FINAL REPORT

Protocol for Tier 2 Evaluation of Vapor Intrusion at Corrective Action Sites

ESTCP Project ER-200707

July 2012

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Acronyms

1,1-DCA	1,1-dichloroethane	NA	not applicable
1,1-DCE	1,1-dichloroethene	NAS	Naval Air Station
1,1,1-TCA	1,1,1-trichloroethane	ND	not detected
1,1,2-TCA	1,1,2-trichloroethane	NIOSH	National Institute for Occupational Safety and Health
ANOVA	Analysis of Variance	NJDEP	New Jersey Department of Environmental Protection
API	American Petroleum Institute	NM	no measurement
ASTM	American Society for Testing and Materials	NYDOH	New York Department of Health
ASU	Arizona State University	OU	operable unit
bgs	below ground surface	PCA	1,1,2,2-tetrachloroethane
cis-1,2-DCE	cis-1,2-dicholoroethene	PCE	tetrachloroethene
COC	chemical of concern	PI	principal investigator
COTS	commercial off-the-shelf	POC	point of contact
DNAPL	dense non-aqueous phase liquid	PVC	polyvinyl chloride
DOD	Department of Defense	QA/QC	quality assurance/quality control
DQO	Data Quality Objective	QAPP	Quality Assurance Project Plan
DTIC	Defense Technical Information Center	RPD	relative percent difference
DTW	depth-to-water	SF	standard form
EIOU	Eastern Industrial Operable Unit	SF_6	sulfur hexafluoride
ESTCP	Environmental Security Technology Certification Program	SOP	Standard Operating Procedure
FOISR	Freedom of Information and Security Review	TCE	trichloroethene
ft	foot, feet	TCEQ	Texas Commission on Environmental Quality
GWBU	groundwater bearing unit	TPH	total petroleum hydrocarbon
HVAC	Heating, Ventilating, and Air Conditioning	trans-1,2-DCE	trans-1,2-dichloroethene
ITRC	Interstate Technology and Regulatory Council	USCS	Unified Soil Classification System
KDHE	Kansas Department of Health and Environment	USEPA	United States Environmental Protection Agency
LCS	laboratory control sample	VC	vinyl chloride
LCSD	laboratory control sample duplicate	VOC	volatile organic compound
MS	matrix spike	WIOU	Western Industrial Operable Unit
MSD	matrix spike duplicate		

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E.0 EXECUTIVE SUMMARY

Project ER-0707 has validated two improved methods for evaluation of vapor intrusion at corrective action sites: i) a Tier 2 screening procedure for evaluation of vapor intrusion from VOCs in groundwater at sites with fine-grained soils at the top of the water table and ii) a streamlined Tier 3 investigation program using building pressure control for application at sites that require building-specific investigations.

E.1 PROJECT OBJECTIVES

For many corrective action sites with VOCs in groundwater, the current regulatory framework requires a building-specific investigation of vapor intrusion if the concentrations of specific VOCs such as PCE, TCE or benzene in groundwater are above federal drinking water standards and buildings are present within 100 ft (e.g., USEPA, 2002). In many cases, the scope of the required building-specific investigation is not clearly defined in applicable regulatory guidance. However, multiple sampling events are increasing being required to characterize potential temporal variability in vapor intrusion.

The overall objective of this project has been to develop and validate simple procedures for i) Tier 2-level site-specific evaluation and screening, and ii) limited Tier 3 field investigation of the vapor intrusion pathway. These procedures utilize easily obtained site-specific information to support a realistic site-specific pathway assessment that, in many cases, requires significantly less effort than is currently required. The Tier 2 screening procedure is applicable to sites with fine-grained soils at the water table that serve to reduce the migration of VOCs from groundwater to deep soil gas. At these sites, the reduced migration of VOCs into the vadose zone justifies application of higher groundwater screening concentrations for the vapor intrusion pathway (i.e., screening concentrations 100x higher than the default, Tier 1, screening concentrations developed to be protective for all sites). The Tier 3 investigation procedure is applicable to sites that require testing of indoor air for the evaluation of vapor intrusion. The Tier 3 procedure involves the collection in indoor air samples under controlled negative pressure building conditions (i.e., with vapor intrusion "on") and controlled positive pressure building conditions (i.e., with vapor intrusion "off"). This investigation procedure reduces the need for multiple sampling events by ensuring that conditions are favorable for vapor intrusion during the scheduled sampling event. In addition, the procedure identifies the contribution of indoor

sources by characterizing indoor air quality when vapor intrusion is “off”. Finally, the procedure can be implemented without the collection of sub-slab samples, reducing the scope and intrusiveness of the building sampling program.

E.2 TECHNOLOGY DEMONSTRATION

The Tier 2 screening procedure was validated though a field demonstration conducted at seven sites while the Tier 3 investigation procedure was validated through a field demonstration conducted at six sites (see Table E.1).

Table E.1: Demonstration Sites

Site Name	Site Location	Type of Demonstration
Former Pioneer Dry Cleaner	Houston, Texas	Tier 2
Travis AFB	Fairfield, California	Tier 2 and Tier 3
Naval Air Station, Jacksonville	Jacksonville, Florida	Tier 3
Parris Island Marine Base	Parris Island, South Carolina	Tier 2* and Tier 3
Tinker AFB	Oklahoma City, Oklahoma	Tier 2 and Tier 3
Hill AFB	Layton, Utah	Tier 2 and Tier 3
Moffett Field NAS	Moffett Field, California	Tier 3
SPAWAR OTC Facility	San Diego, California	Tier 2
NIKE Battery Site PR-58	N. Kingstown, Rhode Island	Tier 2
Industrial Site	Southeast Texas	Tier 2

Note: * = Tier 2 demonstration not completed due to the presence of groundwater at a depth of less than 5 ft bgs.

E.2.1 Tier 2 Demonstration

At each Tier 2 demonstration site, the field program involved: i) measurement of soil characteristics though field and laboratory measurements in order to determine the best method for identification of sites with fine-grained soils at the water table and ii) measurement of VOC concentrations in groundwater and soil gas in order to determine the VOC attenuation from groundwater to deep soil gas (see Figure E.1). At each demonstration site, the measurements were conducted three locations in order to determine the consistency in results across the site. This demonstration program yielded groundwater to deep soil gas attenuation factors for seven sites covering a range of soil characteristics allowing validation of the hypothesis that VOC attenuation is higher at sites with fine-grained soils at the water table.

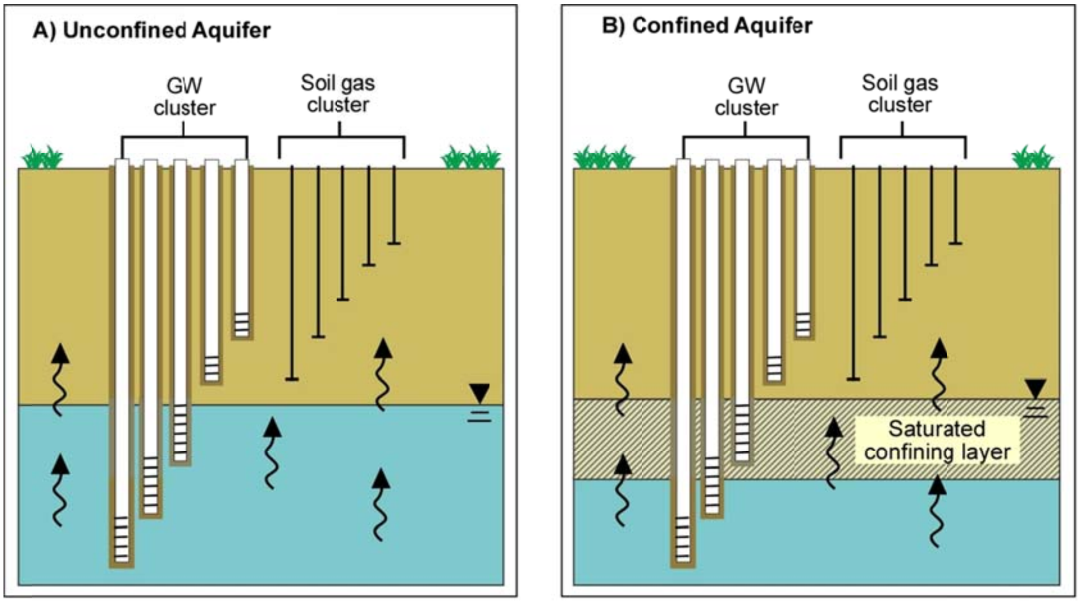

Figure E.1: Conceptual plan for field validation of Tier 2 vapor intrusion screening criteria.

E.2.2 Tier 3 Demonstration

At each Tier 3 demonstration site, the field involved: i) control of building pressure to create negative and then positive building pressure conditions, ii) measurement of pressure gradients across the building envelope and building foundation, and iii) measurement of radon, indoor tracer gas, and VOC concentrations in in indoor air and sub-slab soil gas under each pressure condition (see Figure E.2). At two of the demonstration sites (Hill AFB and Moffett Field), measurements were made under baseline (uncontrolled) building pressure conditions and at these two locations, the procedure was conducted twice in order to evaluate the reproducibility of the results. The results of the demonstration program supported an evaluation of i) the ability to evaluate building foundation permeability based on measurement of cross-foundation pressure gradients, ii) the effect of building pressure control on the movement of soil gas into buildings, and iii) the utility of sampling under controlled building pressure conditions for the evaluation of vapor intrusion.

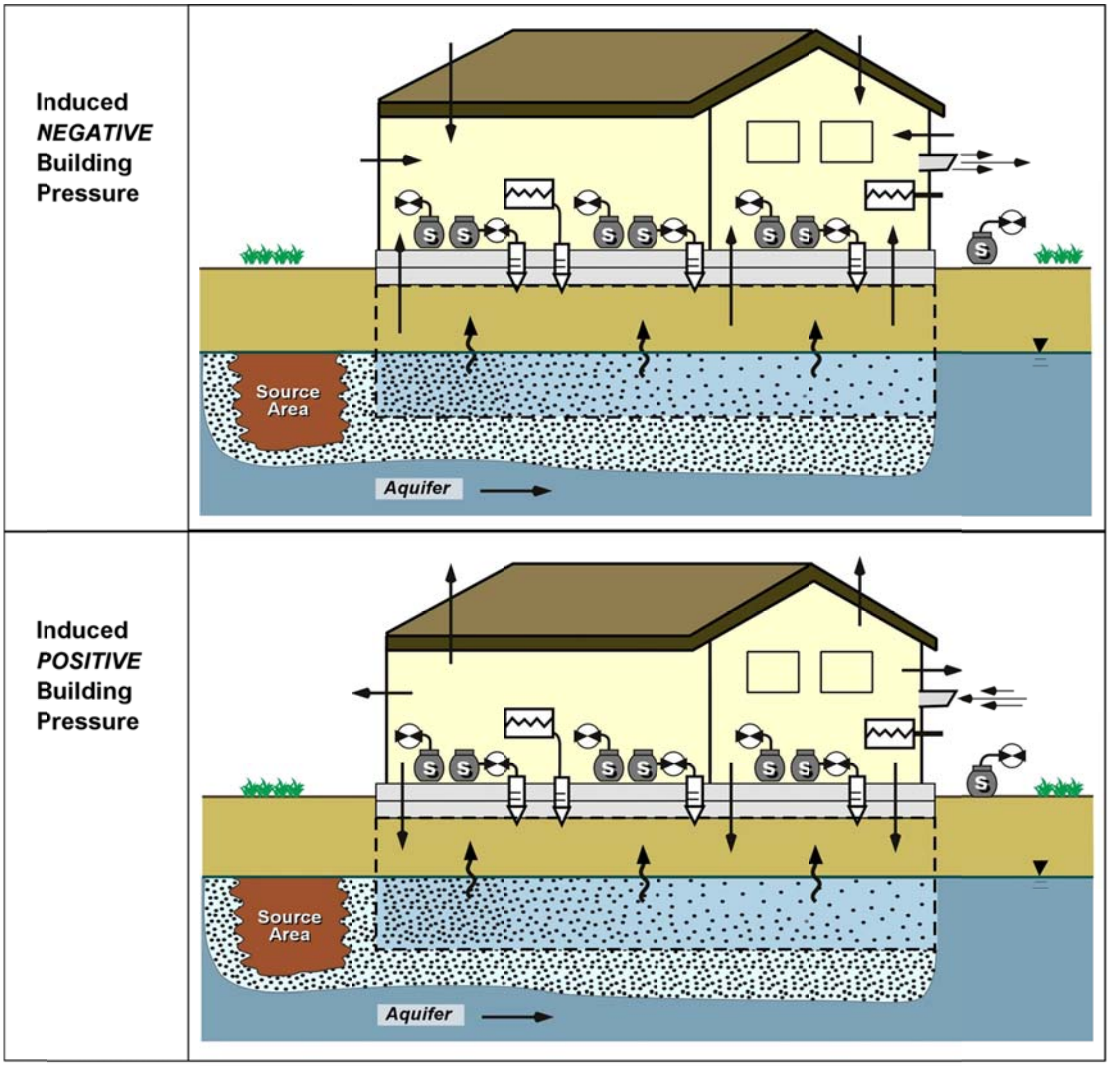

Figure E.2: Conceptual basis for validation of Tier 3 evaluation of vapor intrusion.

E.3 DEMONSTRATION RESULTS

The results from the field demonstrations served to validate both the Tier 2 screening procedure and the Tier 3 investigation procedure.

E.3.1 Results from Tier 2 Demonstration

The field investigation program demonstrated higher attenuation of VOCs from groundwater to deep soil gas at sites with fine-grained soils at the water table (see Table E.2). The geometric mean attenuation factor for the fine-grained soil sites was 3.5 x 10^{-5} while the geometric mean attenuation factor for coarse-grained soil sites was 1.9 x 10^{-2}, a 500-fold difference in attenuation between the two types of sites. Based on this observed difference in VOC attenuation, we recommend that groundwater screening concentrations at fine-grained soil sites can be increased by 100x over the default (i.e., Tier 1) screening values determined to be protective for all types of sites. The 100x increase is a conservative accounting of the increased VOC attenuation observed at fine-grained soil sites.

Table E.2: Groundwater to deep soil gas attenuation factors measured at the demonstration sites

Site	Attenuation Factor (GW to Deep SG)[1]
Sites Classified as Fine-Grained Soils at the Water Table	
Fmr. Pioneer Cleaners	$<8.5 \times 10^{-6}$
Tinker AFB	3.3×10^{-4} ($<2.5 \times 10^{-5} – 2.2 \times 10^{-2}$)
SPAWAR OTC	1.5×10^{-5} (1.4×10^{-5} - 1.5×10^{-5})
Sites Classified as Medium or Coarse-Grained Soils at the Water Table	
Travis AFB[2]	1.0×10^{-2} ($1.0 \times 10^{-3} – 2.9 \times 10^{-2}$)
NIKE Battery PR-58	3.3×10^{-3} (2.8×10^{-4} - 2.1×10^{-2})
Hill AFB	2.8×10^{-2} ($1.7 \times 10^{-2} – 5.2 \times 10^{-2}$)
SE Texas Industrial Site	0.15 (0.026 - 0.61)

(1) Geometric mean (range) of 5 to 6 individual groundwater to deep soil gas attenuation factors except for Former Pioneer Cleaners site. At Former Pioneer Cleaners site, attenuation factor calculated based on maximum VOC concentration in groundwater and VOC detection limit in soil gas because no VOCs were detected in any soil gas samples.

(2) Travis AFB was classified as a Medium or Coarse-Grained soil site based on the field measured soil permeability. For Travis AFB, visual inspection of the soil cores yielded a Fine-Grained Soils classification. Travis AFB was the only site where these two methods yielded different classification results.

The demonstration program evaluated a number of methods for accurate identification of fine-grained soil sites. Field-measured soil permeability was found to be the most accurate classification method with a field-measured soil permeability of less than 1×10^{-9} cm^2 indicative of a fine-grained soil site with high VOC attenuation from groundwater to deep soil gas. The determination of soil type based on visual inspection of soil cores as reflected in the soil boring logs provided an accurate classification for six of the seven demonstration sites. Travis AFB was classified as Medium or Coarse-Grained based on the field-measured soil permeability but Fine-Grained based on visual inspection of the soil cores. Laboratory measured native hydraulic conductivity and soil moisture content were not determined to be useful for site classification.

E.3.2 Results from Tier 3 Demonstration

The field investigation program demonstrated that a building-specific investigation program utilizing sampling under controlled building pressure conditions provides an improved understanding of the potential for vapor intrusion in the building. The control of building pressure successfully controlled the flow of soil gas through the building foundation. Controlled negative building pressure supported the flow of soil gas into the building, as documented by radon concentrations in indoor air greater than the concentration in ambient air. Controlled positive building pressure suppressed the flow of soil gas into the building, as documented by radon concentrations in indoor air equal to the concentration in ambient air (see Figure 6.3.2). The response of VOCs originating from the subsurface was similar to radon. In contrast, the indoor air concentration of VOCs originating from above ground sources showed little difference between the negative and positive pressure conditions.

An expanded version of the Tier 3 demonstration program was implemented in two buildings (ASU Research House at Hill AFB, and Building 107 at Moffett Field). This expanded program included sampling under baseline (uncontrolled) conditions and two rounds of sampling to evaluate reproducibility. For both of these buildings, the results from the two rounds were comparable, demonstrating that the procedure provides reproducible results. At the ASU Research House, no vapor intrusion was observed under baseline conditions. However, vapor intrusion was induced under negative pressure conditions. Other data collected from the house indicates episodic vapor intrusion occurs under uncontrolled conditions (i.e., vapor intrusion occurs during some time periods but not others). The results from this building demonstrate that the Tier 3 investigation procedure reduces the uncertainty associated with temporal variability in vapor intrusion.

E.4 COST ASSESSMENT

Both of the validated procedures have the potential to reduce vapor intrusion investigation costs.

E.4.1 Cost for Implementation of the Tier 2 Screening Procedure

The Tier 2 screening procedure involves i) identification of sites with fine-grained soils at the water table and ii) application of a 100x adjustment factor to Tier 1 screening criteria to account for higher VOC attenuation observed at such sites (see Section 6.4). The estimated time required to implement and document this procedure ranges from three hours (using visual inspection of soil cores or boring logs) to 10 hours (using field measurement of soil permeability). Assuming a labor rate of $100/hr, **the estimated cost for implementation of this screening procedure at a site is $300 to $1000.** For sites where application of the higher groundwater screening concentration eliminates the need to conduct an additional evaluation of the vapor intrusion pathway, application of the screening procedure is likely to save at least $10,000. The actual cost saving will depend on the scope of the avoided field investigation (e.g., the number of buildings where additional investigation is not required).

E.4.2 Cost for Implementation of the Tier 3 Investigation Procedure

The Tier 3 investigation procedure described in Section 6.5 involves manipulating building pressure and collecting air samples during 3 different pressure conditions: baseline, negative pressure, and positive pressure. Estimated costs to implement the Tier 3 procedure are shown in Table 7.2.2. The sampling itself takes place over the course of 3 days, with 4 to 6 hours per day for each of two persons assumed for equipment checks, setup and pickup. Assuming labor rates of $100/hr for a project scientist/engineer and $150/hr for a senior scientist/engineer, **the estimated cost for implementation of Tier 3 investigation procedure is $8,600 per building including project planning and reporting costs.** This cost estimate assumes that the program is implemented by an experienced field team and that the program is conducted at four or more buildings at a single site. The cost for initial implementation by an inexperienced team or for implementation at one to three buildings at a single site would be higher. Using similar assumptions, the estimated cost for implementation of typical building sampling program (i.e., collection of indoor and sub-slab samples under uncontrolled conditions) is $7,800. Thus the Tier 3 procedure is more expensive than a single round of traditional sampling. However, the procedure is less expensive than two or more rounds of traditional sampling.

1.0 INTRODUCTION

This report presents the results from ER-0707, Protocol for Tier 2 and Tier 3 Evaluation of Vapor Intrusion at Corrective Action Sites.

1.1 BACKGROUND

Since 2000, regulators and the regulated community have become increasingly concerned about the potential for exposure to volatile organic compounds (VOCs) through vapor intrusion to indoor air at sites with contaminated soil or groundwater. Relatively few vapor intrusion case studies are available in the published literature (e.g., Folkes et al., 2009; Eklund and Simon, 2007; DiGiulio and Paul, 2006; Sanders and Hers, 2006). However, detailed investigations at a limited number of corrective action sites have documented elevated levels of chlorinated VOCs in houses located above contaminated groundwater (Tillman and Weaver, 2005; DiGiulio, Paul et al., 2006). In response, the United States Environmental Protection Agency (USEPA) and many state regulatory agencies have issued guidance specifying screening and field investigation procedures for the identification of vapor intrusion impacts at corrective action sites. Although the specific recommended investigation procedures vary significantly between guidance documents, the majority of these documents utilize a step-wise evaluation process that includes preliminary screening followed by field investigation, if needed. Of the available regulatory guidance on vapor intrusion, the USEPA guidance (USEPA, 2002) is currently most widely applied. This guidance document has been formally adopted by some states (e.g., Ohio) and is also widely used in states that have not issued their own guidance documents. The USEPA Vapor Intrusion Guidance recommends the following step-wise evaluation approach:

Presence of Volatile Chemicals: Vapor intrusion is a potential concern at sites with soil or groundwater impacted by volatile chemicals. Corrective action sites without volatile chemicals (typically defined by vapor pressure and/or Henry's Law constant) require no further evaluation for vapor intrusion. Example volatility criteria are as follows:

- USEPA (2002): Volatile chemicals are defined based on Henry's Law Constant of greater than 1×10^{-5} atm-m^3/mol.
- NJDEP (2006): Volatile chemicals are defined based on Henry's Law Constant of greater than 1×10^{-5} atm-m^3/mol and a vapor pressure of greater than 1 mm Hg.

Pathway Screening Criteria: For sites with volatile chemicals in soil or groundwater, most regulatory guidance provides conservative screening criteria for preliminary evaluation of the vapor intrusion pathway. Screening criteria are typically provided for groundwater and soil gas and less commonly for soil. These criteria are typically used to evaluate the likelihood of whether VOCs are migrating away from a source area at concentrations that could cause a vapor intrusion impact. Although exceedances of these criteria do not indicate that a vapor intrusion impact has occurred or will occur, additional investigation of vapor intrusion is required if the maximum VOC concentration is greater than the screening value within a defined distance (typically 100 feet [ft]) of a vapor intrusion receptor (i.e., a current or future building). For some common chemicals of concern (COCs), the USEPA screening criteria for groundwater are equal to drinking water standards. In addition, some soil gas screening criteria are less than or equal to analytical detection limits. As a result, few corrective action sites are screened out of further evaluation using these criteria.

Building-Specific Evaluation: For sites with volatile chemicals present at concentrations above the screening criteria, most guidance documents require a field investigation to determine the presence or absence of vapor intrusion impacts to near-by buildings (commonly defined as within 100 ft of VOC impacts). When conducting a site-specific field investigation, the USEPA guidance recommends collection of below-foundation (i.e., sub-slab) gas samples followed by simultaneous below-foundation and indoor air samples, if needed. The USEPA guidance raises a number of data quality issues to be addressed as part of the field investigation including: indoor sources of VOCs (background), spatial variability, temporal variability, and sample collection and analytical variability. However, the guidance document does not provide a clear recommendation on the amount of data needed to account for these sources of variability and to make a definitive determination of the presence or absence of a vapor intrusion impact. In the absence of clear guidance on the scope of the field investigation, the investigation approaches adopted by individual investigators have varied widely. As a result, disagreements may arise between parties involved at a site regarding the adequacy of a field investigation at a specific building.

Although most state vapor intrusion guidance documents utilize a step-wise investigation approach similar to the USEPA guidance, most guidance documents utilize very low screening criteria for the preliminary evaluation and some states (e.g., New York) do not allow screening based on subsurface VOC concentrations, but instead require indoor air testing at all field investigation sites (NYDOH, 2006). In addition, the USEPA has indicated that revised vapor intrusion guidance due in 2012 is unlikely to allow screening of the vapor intrusion pathway based solely on soil gas concentration results (USEPA, 2010). As a result, field investigations of the vapor intrusion pathway are required at a majority of sites with subsurface volatile chemical impacts.

1.2 OBJECTIVE OF THE DEMONSTRATION

The overall objective of this project has been to develop simple procedures for i) Tier 2-level site-specific evaluation and screening, and ii) limited Tier 3 field investigation of the vapor intrusion pathway. These procedures utilize easily obtained site-specific information to support a realistic site-specific pathway assessment involving significantly less effort than is currently required. The specific project objectives are as follows:

- Evaluate soil texture and moisture content as factors affecting attenuation of VOCs migrating from groundwater into deep soil gas.
- Develop a Tier 2 vapor intrusion pathway screening procedure that incorporates the effect of soil texture and moisture content on VOC attenuation across the groundwater interface.
- Evaluate the utility of building pressure control to provide an improved understanding of the impact of vapor intrusion and indoor sources of VOCs on indoor air quality.

- Develop a Tier 3 focused field investigation procedures for the evaluation of vapor intrusion based testing under controlled building pressure.
- Validate the Tier 2 screening procedure and Tier 3 focused field investigation by application at well characterized vapor intrusion sites.

The progress and results of this demonstration have been documented in a series of reports as follows:

1) *Proposed Tier 2 Screening Criteria And Tier 3 Field Procedures For Evaluation Of Vapor Intrusion (Issued February 2008; Revised August 2008)*: Documents results of literature review and survey and presents Tier 2 and Tier 3 vapor intrusion evaluation procedures for field validation.

2) *Demonstration Plan for Field Validation Program (Issued June 2008, Revised October 2008)*: Provides detailed design of field validation program for Tier 2 and Tier 3 vapor intrusion evaluation procedures. Also presents selection of the first set of sites for the field demonstration.

3) *Results and Lessons Learned Interim Report (Issued October 2009, Revised April 2010)*: Presents interim results from 3 demonstration sites for Tier 2 procedure and 4 field demonstration sites for Tier 3 procedure. Note that project plan provides for a go-no go decision point following completion of investigations at the first set of demonstration sites.

4) *Final Report (This Report) and Cost and Performance Report*: Presents final results from all field demonstration sites and presents validated Tier 2 and Tier 3 protocols for evaluation of vapor intrusion.

1.3 REGULATORY DRIVERS

At a limited number of sites in the U.S., migration of volatile organic compounds (VOCs) from affected groundwater via vapor phase diffusion has impacted indoor air quality in overlying structures, posing a potentially significant, yet previously unrecognized human health concern for such properties. To address this concern, the USEPA has issued the "Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils," (USEPA 2002), providing conservative screening criteria for various VOCs in groundwater. As discussed in Section 1.1, these conservative screening values eliminate few sites and, as a result, a majority of sites with VOCs in groundwater require field investigation of the vapor intrusion pathway. The high level of conservatism in the USEPA and state guidance reflects the current limitations of our understanding of the physical and chemical processes that contribute to the attenuation of vapors along the vapor intrusion pathway. Development of a validated Tier 2 vapor intrusion screening procedures will serve to reduce the number of sites where detailed field investigations are required to evaluate the vapor intrusion pathway. Development of a validated Tier 3 vapor intrusion investigation procedure will improve the efficiency of the sites-specific filed investigation, when required.

2.0 TECHNOLOGY

This technology demonstration project has developed and validated i) a Tier 2 vapor intrusion screening procedure based on easily measured site-specific characteristics, and ii) a streamlined Tier 3 evaluation procedure to determine the presence or absence of a vapor intrusion impact to a specific building. The screening procedures can be used individually or together to provide maximum flexibility for cost-effective evaluation of vapor intrusion at each site.

2.1 TECHNOLOGY DESCRIPTION

Tier 2 Screening Procedures: The groundwater-soil gas interface is a key target for site-specific evaluation because: i) transport across this interface varies significantly (>100x) between sites making the Tier 1 default overly conservative for a large proportion of sites evaluated, and ii) easily obtained site-specific data can be used to support a less conservative evaluation. At the groundwater-soil gas interface, a high moisture content, fine-grained soil layer serves as a significant barrier to the vertical migration of VOCs towards buildings. As a result, VOC attenuation along the vapor intrusion pathway at sites with these soil layers can be much higher than at sites where these barriers to vertical diffusion are absent.

For this demonstration, we measured VOC attenuation from shallow groundwater through the soil column at seven sites exhibiting a variety of soil-type characteristics. Sample collection and analysis was conducted in a consistent manner across the sites, providing a comparable data set for accurate assessment of the differences in VOC attenuation between these sites. The results of this demonstration serve to document the higher VOC attenuation that occurs at sites with fine-grained soils at the water table. This, in turn, validates the use of higher Tier 2 screening criteria at sites with these documented soil conditions.

Streamlined Tier 3 Evaluation Procedure: When using indoor air sampling to evaluate vapor intrusion, an investigator must address two confounding issues: i) indoor sources of VOCs, and ii) temporal variability in vapor intrusion. The Tier 3 evaluation procedure addresses both of these issues using a streamlined investigation program that can be completed during a single three-day sampling event. This streamlined investigation protocol uses induced negative building pressure to ensure that vapor intrusion is "on" during one sample event and induced positive building pressure to ensure that vapor intrusion is "off" during a second sampling event (see Figure 2.1.1). Because radon is a naturally-occurring tracer for soil gas, radon concentrations in indoor air can be used to verify the effectiveness of the induced building pressure for controlling the movement of soil gas into the building. VOC concentration results for indoor air ambient air samples collected during these two sample events are used to identify the primary sources of detected VOCs.

For this project, the pressure control investigation procedure was demonstrated in six buildings. The results indicate that small (approximately 1Pa) pressure gradients are sufficient to control the flow of soil gas through the building foundation. VOC concentrations measured in indoor air under these controlled building pressure conditions can be used to identify the primary source of the VOCs and to evaluate the potential for vapor intrusion for a range of building pressure conditions. These results validate the use of the streamlined Tier 3 investigation procedure for the evaluation of vapor intrusion at sites where a building-specific investigation is required.

Controlled <u>negative</u> building pressure: Vapor intrusion is "on"

Controlled <u>positive</u> building pressure: Vapor intrusion is "off"

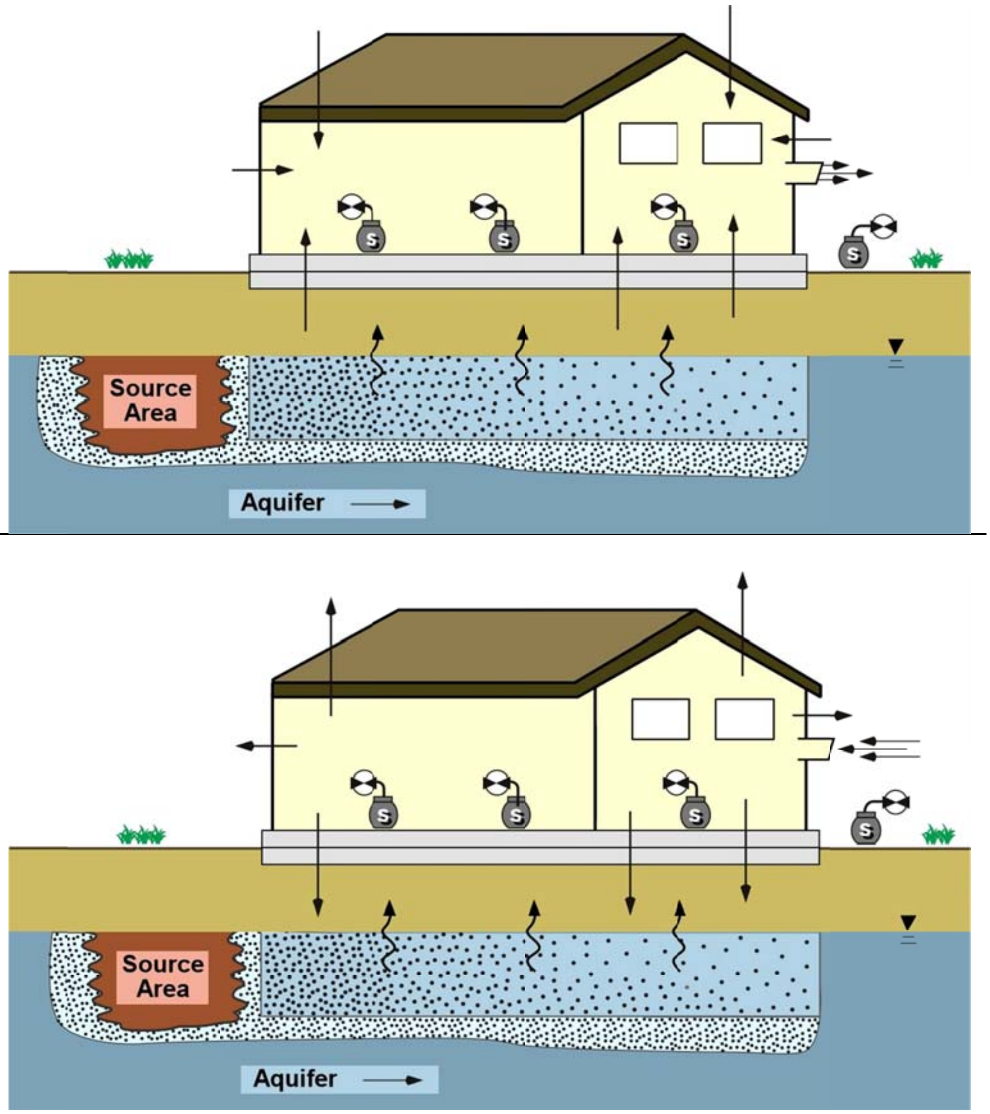

Figure 2.1.1: Conceptual illustration of building pressure control for the building-specific evaluation of vapor intrusion

2.2 TECHNOLOGY DEVELOPMENT

The two vapor intrusion evaluation procedures were developed during the first phase of this project based on a review of regulatory guidance documents and peer-reviewed literature and survey of vapor intrusion experts. The goals of this review and survey were i) to identify key points along the vapor intrusion pathway were the magnitude of VOC attenuation is expected to vary significantly between sites, and ii) to develop investigation procedures for these points that could be used to support an improved evaluation of the vapor intrusion pathway. Based on the results of the review and survey, the project was focused on two key interfaces: i) the groundwater-vadose zone interface, and ii) the building foundation. For each of these two interfaces, investigation methods were developed that would provide an improved site-specific understanding of vapor intrusion. Following completion of the first half of the demonstration program, both investigation procedures were refined through minor adjustments. The initially-proposed procedures and their bases are described in the project report *Proposed Tier 2 Screening Criteria And Tier 3 Field Procedures For Evaluation Of Vapor Intrusion* (Issued February 2008; Revised August 2008). The final refined procedures and the basis for the modifications are documented in the project report *Results and Lessons Learned Interim Report* (Issued October 2009, Revised April 2010). These procedures are summarized below.

<u>Tier 2 Screening Procedure, Sites with Confining Layers or Fine Grained Soils at the Groundwater Interface</u>: The review and survey conducted to identify key interfaces along the vapor intrusion pathway highlighted importance of high-moisture-content fine-grained soils for limiting the diffusion of VOCs from groundwater into the vadose zone. This suggested that VOC migration from a confined aquifer to vadose-zone soils will be limited. In addition, VOC migration from groundwater at unconfined aquifer sites with fine-grained soils is likely to be significantly lower than at sites with coarse-grained soils. Our hypothesis was that we would observe at least 10x greater VOC attenuation at sites with fine-grained soils at the groundwater interface as compared to sites with coarse-grained soils.

Use of groundwater interface soil type for Tier 2 screening would involve the following steps:

- *<u>Evaluation of Soil Type at Water Table</u>*: Demonstration of a fine-grained soil layer above the groundwater interface based on either evaluation of soil boring logs or field measurement of soil permeability in the deep vadose zone.

- *<u>Tier 2 Screening Values</u>*: For sites with these fine-grained soil conditions, the VOC attenuation measured through the Tier 2 demonstration program should support groundwater screening values higher than the generic Tier 1 screening values. Although the original project hypothesis was that at least 10x higher attenuation would be observed at fine-grained soil sites, the observed difference in attenuation was 500x. Based on the results of this field validation program, a 100x adjustment to Tier 1 screening values is recommended based on the documentation of fine-grained soils at the water table.

The impact of an aquifer confining layer or fine-grained soil layer on VOC attenuation has been evaluated through the measurement of soil conditions and VOC concentrations at seven demonstration sites. The demonstration sites have been selected to cover sites with a range of soil characteristics in order to clearly document the differences in VOC attenuation between sites.

<u>Tier 3 Investigation Procedure, Use of Building Pressure Control</u>: Although building foundation permeability has been identified as an important site characteristic for vapor intrusion, the peer-reviewed literature and regulatory guidance do not provide accepted methods for the evaluation of foundation permeability. The proposed Tier 3 investigation procedure included two components: i) a method to evaluate building foundation permeability, and ii) a streamlined

sampling program to evaluate the potential for vapor intrusion at a building and to identify the sources of VOCs detected in indoor air through a single sampling event.

Although measurement of building foundation permeability did not prove useful, the Tier 3 procedure of measuring VOC concentrations in indoor air under controlled building pressure conditions was validated. Use of building pressure control for an expedited Tier 3 field evaluation would involve the following steps:

- *Control of Building Pressure*: Control building pressure conditions using a fan in a window or door to create negative building pressure and positive building pressure.

- *Measurement of Vapor Intrusion During Controlled Building Pressure*: Measure VOC and radon concentrations in indoor air during the induced negative building pressure event to evaluate indoor air quality under conditions that support vapor intrusion and measure VOC and radon concentrations in indoor air during an induced positive building pressure event to evaluate indoor air quality under conditions that inhibit vapor intrusion. The program of sampling under controlled building pressure conditions controls for temporal variability in buildings with episodic vapor intrusion and provides an improved ability to distinguish between indoor and subsurface sources of VOCs.

- *Vapor Intrusion Determination*: Based on the effect of building pressure on indoor air quality, the potential for vapor intrusion impacts to building is determined in a single sampling event.

As discussed in Sections 5 and 6 of this report, our demonstration results have validated the use of building pressure control to identify the sources of VOCs detected in indoor air and to mitigate temporal variability in vapor intrusion. However, the demonstration results have not shown that measurement of building foundation permeability provides an improved understanding of the potential for vapor intrusion. As a result, the validated Tier 3 investigation procedure described in Section 6.5 of this report utilizes building pressure control but does not include characterization of building foundation permeability.

2.3 ADVANTAGES AND LIMITATIONS OF THE TECHNOLOGY

The use of a tiered approach for the evaluation of correction action sites has provided a cost-effective framework for focusing detailed site evaluations on exposure pathways that represent the greatest potential risk and/or remediation cost. Tier 1 uses generic screening criteria to eliminate the lowest risk pathways, Tier 2 uses limited site-specific information to support the use of less conservative screening criteria, where appropriate, and Tier 3 allows for detailed site investigations to accurately assess risk when warranted. States that have adopted this tiered evaluation process within the context of risk-based corrective action have realized significant cost savings for their corrective action programs (Connor and McHugh, 2002).

As described above, USEPA and many states' vapor intrusion guidance documents contain conservative (Tier 1) screening values and also provide some guidance for conducting detailed

(Tier 3) field investigations of vapor intrusion. However, there is a significant gap in the current vapor intrusion evaluation process contained in USEPA and state vapor intrusion guidance due to the absence in the guidance of meaningful Tier 2 screening criteria that can be adjusted to reflect easily measured site characteristics that limit the migration of VOCs along the vapor intrusion pathway. As a result, the USEPA guidance provides no alternative to a detailed field investigation of vapor intrusion at sites with >5 µg/L benzene or >5 µg/L TCE in groundwater (i.e., sites with VOCs in groundwater at concentrations above federal drinking water standards).

Advantages: The conservative procedures for evaluation of vapor intrusion at corrective action sites that are presented in USEPA and state guidance reflect the limitations in our current understanding of the physical and chemical processes that contribute to vapor intrusion. However, researchers are beginning to gain some understanding of the importance of key site characteristics in controlling vapor intrusion attenuation factors. Henry Schuver of the USEPA has estimated that site-specific factors can contribute ***up to six orders of magnitude in uncertainty and variability in vapor intrusion*** (Schuver, 2005). As a result, Tier 1 screening criteria developed to be protective over a broad range of site conditions are extremely conservative for a great majority of sites. However, because of this high level of site-to-site variability, Tier 2 screening criteria that have been adjusted to reflect key site characteristics would allow a reduction in the level of conservatism in site screening without compromising the protectiveness of the guidance. The field demonstration will validate such Tier 2 screening procedures. Clear validation of these procedures will demonstrate their protectiveness and facilitate regulatory acceptance.

At sites where a field investigation is required to determine the presence or absence of a vapor intrusion impact, currently available guidance does not clearly define the required scope of the field investigation. Many current guidance documents recommend that large amounts of data be collected over extended periods of time. Even at sites where the initial field investigation provides no evidence of a vapor intrusion impact, long-term monitoring is sometimes required to demonstrate long-term protectiveness. At some sites, high levels of variability in VOC concentrations or sporadic detections of COCs in some samples have prevented a definitive determination of the presence or absence of a vapor intrusion impact. At Hill Air Force Base (AFB), for example, a large number of residences have been included in a long-term indoor air-monitoring program because occasional detections of site COCs in some residences cannot be definitively attributed to either vapor intrusion or to other sources. For these sites, a focused Tier 3 field investigation procedure that reduces the scope of the required field investigation while increasing the ability to definitively determine the presence or absence of a vapor intrusion impact can significantly reduce the time and expense associated with the filed investigation of vapor intrusion.

Limitations: The Tier 2 screening procedures will be useful only at sites that meet the criteria for application (i.e., sites with high moisture content fine-grained soil layers at or above the water table. Sites with exclusively sandy soils and sites in dry climates with low moisture content soils will not benefit from the higher Tier 2 screening criteria). The Tier 2 screening procedure should not be applied to sites where the depth to groundwater is less than 5 ft bgs.

The streamlined Tier 3 evaluation procedure is targeted towards characterizing and controlling the building-specific factors that contribute to variability in VOC attenuation and associated vapor intrusion impacts. The method is not applicable to very large or very leaky building where the building pressure cannot be easily controlled. Depending on the building integrity, buildings larger than 10,000 to 15,000 ft^2 may be difficult to depressurize using a readily available rental fan. If a specific portion of a building is isolated from the rest of the building by interior walls, then the Tier 3 demonstration can be implemented in that portion of the building (see results for Jacksonville NAS and Tinker AFB). In addition, the pressure control method does not eliminate the spatial variability on VOC concentrations that is observed at many investigation sites. At some sites, this spatial variability can make interpretation of the monitoring results more difficult.

The Tier 3 evaluation procedure involves controlled depressurization of the building in order to induce conditions favorable for vapor intrusion. The results from this procedure are likely to be most useful when the results indicate an absence of vapor intrusion. However, when the results do show that vapor intrusion occurs under depressurized conditions, these results will not be directly applicable to normal building operating conditions because the magnitude of vapor intrusion observed under depressurized conditions may be greater than that observed under normal operating conditions. For these cases, the investigator may choose either preemptive mitigation based on the finding of potential vapor intrusion or continued monitoring in order to define the frequency and magnitude of vapor intrusion under normal building operating conditions.

3.0 PERFORMANCE OBJECTIVES

The primary objective of this demonstration study is to develop simple procedures for i) Tier 2-level site specific screening based on soil characteristics, and ii) limited building-focused Tier 3 field investigation of the vapor intrusion pathway. This objective will be met by:

1) Collecting an extensive amount of data related to the specific site conditions that influence VOC attenuation factors at the test sites;
2) Collecting data in a consistent and comparable manner from sites with a broad range of site conditions (i.e., soil characteristics and building characteristics);
3) Analyzing this data to obtain a thorough understanding of how site specific conditions influence vapor intrusion processes; and
4) Documenting the impact of soil characteristics on VOC attenuation from groundwater (Tier 2 evaluation) and documenting the utility of measurement and control of building pressure for evaluation of vapor intrusion impacts (streamlined Tier 3 evaluation).

Specific performance objectives include i) collection of data representative of site conditions, and ii) evaluation of the data to validate improved vapor intrusion investigation criteria. The objectives are summarized in Table 3.1.

Table 3.1: Performance Objectives

Performance Objective	Data Requirements	Success Criteria	Results
Quantitative Performance Objectives			
Collection of data representative of site conditions.	Soil type and moisture content, water elevation, VOC concentrations in groundwater, soil gas, and indoor air, building pressure gradients.	Precision, Accuracy, Completeness, Representativeness, and Comparability as defined in Appendix D of the demonstration plan.	Quantitative objectives for Precision, Accuracy, Completeness, Representativeness, and Comparability were achieved with minor exceptions discussed in Section 6.1.1. The exceptions were typical of any significant environmental field program. The data quality for the demonstration program data set is acceptable and suitable for evaluation of the demonstration performance.
Validation of Tier 2 screening criteria and procedure (Hypothesis: VOC attenuation in the vadose zone is higher at sites with high moisture content fine-grained soil layers on top of the shallowest water-bearing unit (i.e., a confining layer) or within the vadose zone).	1) Measurement of vadose zone attenuation factors at each Tier 2 demonstration site. 2) Identification of the presence or absence of a high moisture content fine-grained soil layer at each site. 3) Evaluation of the association between vadose zone attenuation of VOCs and the presence or absence of a high moisture content fine-grained soil layer.	A statistically significant difference in VOC attenuation between vadose zone attenuation of VOCs at sites with and without a high moisture content fine-grained soil layer. Statistical methods for data analysis are described in Section 5.6.2 of the demonstration plan.	A statistically-significant difference was observed in VOC attenuation between the three sites with fine-grained soils at the water table and the four sites with coarse-grained soils at the water table ($p = 0.01$; Section 6.2.3). Moisture content was not useful for identification of high groundwater to deep soil gas attenuation sites. Field-measured soil permeability was the best method for identification of fine-grained soil sites with high groundwater to deep soil gas attenuation. Visual determination of soil type provided an accurate classification (i.e., high attenuation vs. low attenuation) for six of the seven demonstration sites.

Performance Objective	Data Requirements	Success Criteria	Results
Quantitative Performance Objectives			
Validation of Tier 3 investigation procedure (Hypothesis: manipulation of building pressure to create negative and positive building pressures i) alters the distribution of VOCs in and around the building in a way that helps distinguish vapor intrusion from background VOC sources, and ii) allows measurement of pressure gradients to provide an improved understanding of foundation permeability.)	1) Measurement of VOC distribution in indoor air and sub-slab gas under negative and positive building pressure conditions. 2) Measurement of pressure gradients across building foundation, across building envelope, and in shallow soils below building.	Hypothesis part i: A statistically significant difference in VOC distribution between negative pressure conditions and positive pressure conditions. The expected change in VOC distribution is illustrated in Figure 6.3.1. Statistical methods for data analysis are described in Section 6.3. Hypothesis part ii: A statistically-significant association between foundation permeability and sub-slab to indoor air attenuation factor. Statistical methods for data analysis are described in Section 6.3.	Hypothesis part i: ANOVA demonstrates a statistically significant difference in VOC distribution in indoor air between negative pressure conditions and positive pressure conditions ($p = 0.03$). The change in VOC concentration in indoor air was different depending on the source of the VOC (i.e., above ground or subsurface) as illustrated in Figure 6.3.1. However, the predicted change in VOC concentration in sub-slab samples was not observed. Hypothesis part ii: No statistically-significant association between foundation permeability and sub-slab to indoor air attenuation factor was observed.
Qualitative Performance Objectives			
Development of Tier 2 screening criteria and procedure.	Field-tested investigation procedures.	Procedures for implementation of Tier 2 screening (see Section 5.6.4 of the demonstration plan.)	Validated procedures for implementation of the Tier 2 screening procedure are described in Section 6.4 of this report.
Development of Tier 3 investigation procedure.	Field-tested investigation procedures.	Procedures for implementation of streamlined Tier 3 investigation (see Section 5.6.5 of the demonstration plan.)	Validated procedures for implementation of the streamlined Tier 3 investigation procedure are described in Section 6.5 of this report.

3.1 PERFORMANCE OBJECTIVE: COLLECTION OF DATA REPRESENTATIVE OF SITE CONDITIONS

The collection of site data that is representative of actual site conditions has been achieved by adhering to the sampling and analysis procedures specified in Section 5. Quality assurance/quality control (QA/QC) samples have been collected to allow for the evaluation of data precision, accuracy, completeness, representativeness, and comparability.

3.1.1 Data Requirements

QA/QC samples have been collected to ensure that the collected data are representative of actual site conditions. As detailed in the Quality Assurance Project Plan (QAPP) (see Appendix D of the demonstration plan), the specific QA/QC samples collected vary based on type of sample and analysis method but typically include field duplicates, field blanks, and standard laboratory QA/QC samples. Field duplicate samples are collected at a minimum rate of one per 20 samples or one per sample event, whichever is greater.

3.1.2 Success Criteria

QA/QC samples have been evaluated to determine the data precision, accuracy, completeness, representativeness, and comparability. Success criteria vary by sample type and are specified in the QAPP (see Appendix D of the demonstration plan). The results of the data quality evaluation are presented in Section 6.1.1 of this report.

3.2 PERFORMANCE OBJECTIVE: VALIDATION OF TIER 2 SCREENING CRITERIA AND PROCEDURES

The hypothesis for validation of the Tier 2 screening criteria is that VOC attenuation in the vadose zone is higher at sites with high moisture content fine-grained soil layers on top of the shallowest water-bearing unit.

3.2.1 Data Requirements

Validation of the Tier 2 screening criteria will require i) documentation of soil type, soil moisture content, and vertical VOC distribution in groundwater and the vadose zone at each demonstration site, and ii) observation of a significantly higher VOC attenuation at sites with high moisture content fine-grained soil layers compared to sites dominated by sandy soils and sites with dryer fine-grained soils. At each demonstration site, soil characteristics and the vertical distribution of VOCs have been characterized at three locations. The use of three sampling locations allows for statistical characterization of the variability in the measured parameters at each site.

3.2.2 Success Criteria

The objective will be considered to be met if a statistically-significant difference in VOC attenuation is observed between sites with high moisture content fine-grained soil layers compared to sites dominated by sandy soils and sites with dryer soils.

3.3 PERFORMANCE OBJECTIVE: VALIDATION OF TIER 3 INVESTIGATION PROCEDURE

The hypothesis for validation of the streamlined Tier 3 investigation is that manipulation of building pressure to create negative and positive building pressures i) alters the distribution of VOCs in and around the building in a way that helps distinguish vapor intrusion from background VOC sources, and ii) allows measurement of pressure gradients to provide an improved understanding of foundation permeability. The procedures to evaluate building foundation permeability are applicable to buildings with concrete foundations (at grade or below grade). The procedures are not directly applicable to buildings with highly permeable foundations such as pier and beam.

3.3.1 Data Requirements

Validation of the Tier 3 field investigation methods will require i) manipulation of building air flow to create negative and positive building pressures, ii) observation of differences in VOC distribution between negative and positive building pressure conditions, and iii) observation of differences in cross-foundation pressure gradients between buildings that correlate to observed differences in the magnitude of vapor intrusion. At each demonstration building, the distribution of VOCs and tracer gases in and around the test building has been characterized by the collection of samples from three sub-slab, three indoor, and one ambient air sample point under negative and positive building conditions. In addition, foundation permeability has been evaluated through the measurement of pressure gradients across the building foundation and across the building envelope.

3.3.2 Success Criteria

The objective will be considered to be met if i) a statistically-significant difference in VOC distribution is observed between negative pressure and positive pressure building conditions, and ii) a statistically-significant association is observed between foundation permeability and VOC attenuation across the building foundation.

3.4 PERFORMANCE OBJECTIVE: DEVELOPMENT OF TIER 2 SCREENING CRITERIA AND PROCEDURES

The goal of the field demonstration for the Tier 2 screening procedure is to produce a validated procedure to apply to other sites with vapor intrusion concerns. The Tier 2 screening procedure will consist of i) procedures for evaluation of soil type and soil moisture to identify sites with high moisture content fine-grained soil layers, and ii) development of an adjustment factor to apply to Tier 1 screening criteria to account for the higher VOC attenuation observed at these sites.

3.4.1 Data Requirements

Development of the Tier 2 screening criteria and procedure will require i) validation of the Tier 2 screening method (see Section 3.2), and ii) feedback from field personnel concerning how the procedure can best be applied to other sites with vapor intrusion concerns.

3.4.2 Success Criteria

The objective will be considered to be met if a simple protocol is developed that provides procedures for i) the identification of sites with high moisture content fine-grained soil layers, and ii) the proper application of the Tier 2 screening criteria at these sites.

3.5 PERFORMANCE OBJECTIVE: DEVELOPMENT OF TIER 3 INVESTIGATION PROCEDURE

The goal of the field demonstration for the Tier 3 investigation procedure is to produce a validated procedure for application of a streamlined building investigation program that provides a reliable determination of the presence or absence of a vapor intrusion concern for that building. The Tier 3 evaluation procedure will consist of procedures for i) control of building pressure to create negative and positive building pressure conditions, ii) a VOC and tracer gas sampling program, iii) pressure gradient measurements, and iv) data interpretation methods.

3.5.1 Data Requirements

Development of the streamlined Tier 3 evaluation procedure will require i) validation of the Tier 3 investigation (see Section 3.3), and ii) feedback from field personnel concerning how the procedure can best be applied to other sites with vapor intrusion concerns.

3.5.2 Success Criteria

The objective will be considered to be met if a simple protocol is developed that provides i) procedures for control of building pressure, sample collection, and measurement of pressure gradients, and ii) guidance for data interpretation to determine the presence or absence of a vapor intrusion concern.

4.0 SITE DESCRIPTION

This demonstration has involved field validation of a Tier 2 screening procedure and a streamlined Tier 3 evaluation procedure. Each procedure has been validated at eight demonstration sites.

4.1 SITE SELECTION

The following criteria were used to identify potential demonstration sites:

4.1.1 General Criteria

Groundwater Contamination: A demonstration site must have a plume of dissolved VOCs, preferably with one or more chlorinated solvents, with concentrations measured in near-by monitoring wells above 100 µg/L. Note that chlorinated VOC concentrations measured at the top on the water-bearing unit are often lower than those measured in traditional monitoring wells. Therefore, if monitoring data are available for the top of the water-bearing unit, lower VOC concentrations (e.g., 10 µg/L) are acceptable.

Site Characterization: A site should be well characterized with regard to site hydrogeology and the nature and extent of dissolved contaminants. A site characterization report should be available providing delineation information for the dissolved plume in the vicinity of the test area and soil boring logs or monitor well logs that document geologic conditions in the test area.

Site Access: Access to the test area or building must be available to conduct the field study. Specific access requirements for each type of procedure are described below.

4.1.2 Characteristics for Validation of Tier 2 Screening Procedure

Source Characteristics: The dissolved groundwater plume should represent the only likely source of VOCs in the test area. In other words, the test area should be located away (i.e., >100 ft) from areas of contaminated soils. Selection of test areas remote from the source area will reduce the potential from vadose sources or lateral migration of vapors to confound the understanding of vertical VOC migration from groundwater.

Vadose Zone Conditions: The presence of high (>100 µg/m3) VOC concentrations in deeper soil gas should be confirmed by soil gas measurements or inferred based on the dissolved plume characteristics. The vadose zone geology should be well characterized through installation of several (6 or more) soil borings. Within the test area, the geology should be relatively uniform with respect to the presence or absence of a fine-grained soil layer. Field validation is planned for sites with and without a wet fine-grained soil layer.

Depth to Groundwater: The depth from the top of the groundwater-bearing unit should be not less than 5 ft and not more than 25 ft below ground surface (bgs).

Site Access: Access to the test area must be available for installation of three monitoring point clusters each with a series of monitoring points spaced from the upper portion of the aquifer through the vadose zone. Ground surface in the test area may be paved or unpaved.

4.1.3 Characteristics for Validation of Tier 3 Procedure

Building Access: Access to the test building must be available for installation of several (three to six) test points through the building foundation. These test points of 1" diameter or less and can be located in storage closets or other out-of-the way locations. It should be possible to create either positive or negative building pressure through manipulation of the building heating, ventilating and air conditioning (HVAC) system or use of a window fan or blower. Building access should be available to conduct a one to three day test involving manipulation of building pressure and the collection of indoor air and sub-slab gas samples.

4.1.4 Identification of Candidate Sites

Candidate sites were identified by distributing the site selection criteria described above to i) DoD environmental managers, ii) personnel at the Texas Commission on Environmental Quality (TCEQ) Dry Cleaner Remediation Program, and iii) personnel at the Kansas Department of Health and Environment (KDHE). Based on the criteria provided, these personnel identified potential sites and provided investigation reports for further review.

4.2 SITE LOCATION AND HISTORY

The demonstration sites, selected based on the selection criteria described above, are listed on Table 4.2.

Table 4.2: Demonstration Sites

Site Name	Site Location	Type of Demonstration
Former Pioneer Dry Cleaner	Houston, Texas	Tier 2
Travis AFB	Fairfield, California	Tier 2 and Tier 3
Naval Air Station, Jacksonville	Jacksonville, Florida	Tier 3
Parris Island Marine Base	Parris Island, South Carolina	Tier 2* and Tier 3
Tinker AFB	Oklahoma City, Oklahoma	Tier 2 and Tier 3
Hill AFB	Layton, Utah	Tier 2 and Tier 3
Moffett Field NAS	Moffett Field, California	Tier 3
SPAWAR OTC Facility	San Diego, California	Tier 2
NIKE Battery Site PR-58	N. Kingstown, Rhode Island	Tier 2
Industrial Site	Southeast Texas	Tier 2

Note: * = Tier 2 demonstration not completed due to the presence of groundwater at a depth of less than 5 ft bgs.

Each of these sites has a dissolved chlorinated solvent plume in shallow groundwater that has migrated away from the source area. Prior to the demonstration, each site had been investigated in sufficient detail to provide an understanding of the site geology and contaminant distribution and to allow identification of appropriate investigation locations.

4.3 SITE GEOLOGY/HYDROGEOLOGY

4.3.1 Former Pioneer Dry Cleaner (Tier 2 Demonstration)

Shallow soils at the Former Pioneer Dry Cleaner site are characterized by clay soils with interbedded layer of silt and clayey or silty sand. Groundwater is initially encountered at a depth of 15 to 28 ft bgs; however, the shallow groundwater-bearing units are generally confined. For the Tier 2 demonstration, this site is representative of sites with moist fine-grained soil layers directly above the shallowest water-bearing unit (i.e., confined aquifer conditions). A conceptual cross-section is provided in Appendix A.1.

4.3.2 Travis AFB (Tier 2 and Tier 3 Demonstration)

Shallow soils at Travis AFB are characterized by low permeability, fine-grained silt and clay with discontinuous sand and silty sand lenses. Groundwater is typically encountered 10 to 15 ft bgs and groundwater elevations fluctuate by 2 to 5 ft between fall and spring. The shallow aquifer is unconfined or semi-confined depending on location. For the Tier 2 demonstration, this site is representative of sites with wet fine-grained soil layers in the vadose zone. A conceptual cross-section is provided in Appendix A.2.

4.3.3 NAS Jacksonville (Tier 3 Demonstration)

The Tier 3 demonstration at NAS Jacksonville was conducted at Building 103 located in Operable Unit 3 (OU3). OU3 is a 134-acre area located south of the major east/west runway. OU3 is underlain by interbedded layers of sand, clayey sand, and clay. The water table at OU3 is located within a few feet of ground surface. Within OU3, groundwater flow within the upper layer of the surficial aquifer is controlled largely by drainage to storm sewer lines.

4.3.4 Parris Island Marine Base (Tier 2 and Tier 3 Demonstration)

The shallow geology at the Parris Island Marine Base is characterized by sand and silty sand with discontinuous layers of silty clay. Groundwater level of the shallow unit typically fluctuates between 5 to 10 ft bgs. However, during the field program shallow groundwater was encountered as shallow as 1 ft bgs.

For the Tier 2 demonstration, this site was intended to be representative of sites with coarse-grained soil layers in the vadose zone. However, as discussed in Section 4.5.4, the depth to groundwater was too shallow to allow completion of the Tier 2 demonstration.

4.3.5 Tinker Air Force Base (Tier 2 and Tier 3 Demonstration)

Shallow soils at Tinker AFB are characterized by low permeability, fine-grained silty clay and clayey silt layers. Groundwater is first encountered 10 to 15 ft bgs in a silty sand layer present at this depth. This shallow groundwater-bearing unit is unconfined. For the Tier 2 demonstration, this site is representative of sites with wet fine-grained soil layers in the vadose zone. A conceptual cross-section is provided in Appendix A.5.

4.3.6 Hill Air Force Base (Tier 2 and Tier 3 Demonstration)

Shallow soils at Hill AFB are characterized by interbedded high permeability sand and silty sand and low permeability silt and clay. Groundwater is first encountered 7 to 12 ft bgs in a silty sand layer present at this depth. This shallow groundwater-bearing unit is unconfined. For the Tier 2 demonstration, this site is representative of sites with fine to medium-grained soils directly above the shallowest water-bearing unit (i.e., unconfined aquifer conditions). A conceptual cross-section is provided in Appendix A.6.

The Tier 3 demonstration was conducted at an unoccupied house south of Hill AFB. Dr. Paul Johnson of Arizona State University (ASU) purchased this house (hereinafter referred to as the "ASU Research House") for use on Strategic Environmental Research and Development Program Project ER-1686.

4.3.7 Moffett Field NAS (Tier 3 Demonstration)

The Tier 3 demonstration was conducted at Building 107 at Moffett Field NAS. Moffett Field is located near San Francisco Bay in California, at the northern end of the Santa Clara Valley Basin. The basin contains interbedded alluvial, fluvial, and estuarine deposits. The uppermost aquifer consists of multiple interconnected permeable lenses made up of silts and sandy silts to medium to coarse gravelly sands. Groundwater is typically encountered 10 to 15 ft bgs.

4.3.8 SPAWAR OTC Facility (Tier 2 Demonstration)

Shallow soils at the SPAWAR OTC Facility are characterized by artificial fill material derived from dredged bay sediments and various road base/construction materials (including gravels). The artificial fill consists of interbedded sand with silty sand, clayey silt, and clay layers. Groundwater is first encountered 10 to 12 ft bgs in a silty sand layer present at this depth. This shallow groundwater-bearing unit is unconfined. For the Tier 2 demonstration, this site is representative of sites with moist fine-grained soil layers in the vadose zone directly above the water table. A conceptual cross-section is provided in Appendix A.8.

4.3.9 NIKE Battery Site PR-58 (Tier 2 Demonstration)

Shallow soils at the NIKE Battery Site PR-58 are of glacial origin characterized by moderate to high permeability interbedded silty sand and gravelly sand layers. Groundwater is first encountered 10 to 11 ft bgs in a gravelly sand layer present at this depth. This shallow groundwater-bearing unit is unconfined, and groundwater flow is to the southeast. For the Tier 2 demonstration, this site is representative of sites with medium-grained soil layers in the vadose zone above the water table. A conceptual cross-section is provided in Appendix A.9.

4.3.10 Industrial Site, Southeast Texas (Tier 2 Demonstration)

Shallow soils at the Industrial Site in Southeast Texas are characterized by low permeability, fine-grained clayey silt and silty sand layers. Groundwater is first encountered 13 to 18 ft bgs in a silty sand layer present at this depth. This shallow groundwater-bearing unit is unconfined. For the Tier 2 demonstration, this site is representative of sites with wet fine to medium-grained soil layers in the vadose zone directly above the water table. A conceptual cross-section is provided in Appendix A.10.

4.4 CONTAMINANT DISTRIBUTION

4.4.1 Former Pioneer Dry Cleaner (Tier 2 Demonstration)

Investigations conducted at the Former Pioneer Dry Cleaner site have documented the presence of elevated concentrations of tetrachloroethene (PCE) and associated degradation products in the shallow groundwater at distances of up to 350 ft downgradient of the dry cleaner facility. Although PCE concentrations are highest in deeper groundwater bearing units, PCE concentrations in the shallowest unit range from 0.18 to 1.3 mg/L at distances of 100 to 300 ft from the Dry Cleaner facility. As a result, this site is appropriate for evaluation of VOC migration from shallow groundwater through the vadose zone (i.e., validation of the Tier 2 evaluation procedure).

4.4.2 Travis AFB (Tier 2 and Tier 3 Demonstration)

The East Industrial Operable Unit (EIOU) and West Industrial Operable Unit (WIOU) at Travis AFB each contain large groundwater plumes with VOCs from several source areas. Plumes from some source areas have commingled. Large areas of groundwater with elevated concentrations of TCE have been delineated in the EIOU and WIOU. Soil gas testing has confirmed the presence of elevated TCE concentrations in shallow soil gas.

4.4.3 NAS Jacksonville (Tier 3 Demonstration)

Investigations conducted in OU3 have documented the presence of elevated VOC concentrations within soil and groundwater in the immediate vicinity of Building 103 at depths of 15 to 20 ft bgs. The primary COCs are PCE, TCE, and related degradation products. Although only limited testing of shallow soils has been conducted, a soil gas survey conducted in 1994 found PCE present at 4,800,000 $\mu g/m^3$ in shallow soil gas (< 5 ft bgs) between Building 103 and Building 106 (located just west of Building 103) confirming that Building 103 is an appropriate location for the Tier 3 demonstration.

4.4.4 Parris Island Marine Base (Tier 2 and Tier 3 Demonstration)

At Site 45, Parris Island Marine Base, PCE originating from a former dry cleaning facility has impacted shallow groundwater. In addition, the sewer line from the facility apparently acted as a secondary source resulting in a complex distribution of PCE and degradation products in shallow groundwater. A sewer line release point appears to be located near the southeast corner on the new dry cleaning facility (a facility that has never handled PCE). PCE concentrations in this area are greater than 1,000 µg/L and a dissolved plume of PCE and degradation products extends to the southeast.

4.4.5 Tinker Air Force Base (Tier 2 and Tier 3 Demonstration)

Multiple sources of TCE have impacted shallow groundwater at Tinker AFB, resulting in several TCE plumes in shallow groundwater. The Tier 2 demonstration was focused on a plume extending east from Building 201. Dissolved TCE concentrations in this area generally range from 100 to 800 µg/L.

The Tier 3 demonstration was conducted in the mechanical room of Building 200. In this area, a release of PCE has impacted shallow soils and groundwater. A prior investigation found PCE concentrations of up to 2,100 µg/m^3 in soil gas collected from below the mechanical room.

4.4.6 Hill Air Force Base (Tier 2 and Tier 3 Demonstration)

TCE is the most widespread and primary COC at Operable Unit 5 (OU5). The primary TCE plume identified at the test area in OU5 is the Tooele Army Rail Shop (TARS) plume. In this area, TCE concentrations in groundwater have been found to exceed 1,000 ug/L. The TARS TCE plume extends approximately 5,000 ft beneath the cities of Sunset and Clinton (test area) to the west-northwest. Other significant COCs include 1,1,1-trichloroethane (1,1,1-TCA) and cis-1,2-dicholoroethene (cis-1,2-DCE).

The Tier 3 demonstration was conducted at the ASU Research House south of the base. A CVOC groundwater plume as well as vapor intrusion into the building had been documented previously (SERDP Project ER-1686).

4.4.7 Moffett Field NAS (Tier 3 Demonstration)

A number of buildings at Naval Air Station Moffett Field, near Palo Alto, CA, are impacted by subsurface sources of TCE and PCE. The building selected for this verification test was Building 107. Building 107 is a small office building overlying the TCE/PCE plume and had detections of TCE and PCE in indoor air prior to the demonstration study.

4.4.8 SPAWAR OTC Facility (Tier 2 Demonstration)

Several previous investigations at the SPAWAR OTC Facility were conducted to characterize TCE, TCE degradation products, and total petroleum hydrocarbons (TPH) in the groundwater, soil and soil gas. The primary COCs in groundwater, soil and soil gas include PCE, TCE, cis-1,2-DCE, trans-1,2-dichloroethene (trans-1,2-DCE), and/or vinyl chloride (VC). Maximum detected concentrations of COCs in each medium are found on the north-northwest side of Building 3. TCE degradation products in the groundwater have migrated off-site both to the southwest (towards the test area) and to the north-northwest.

4.4.9 NIKE Battery Site PR-58 (Tier 2 Demonstration)

Investigations conducted at NIKE Battery Site PR-58 have documented a main source area with the possible presence of subsurface DNAPL in the vicinity of existing monitoring well cluster MW03-14 (located immediately east of the former missile silo area and northwest of the test area). The primary COCs in the groundwater include 1,1,2,2-tetrachloroethane (PCA), PCE, TCE, 1,1,2-trichloroethane (1,1,2-TCA), cis-1,2-DCE, trans-1,2-DCE, 1,1-dichloroethene (1,1-DCE), and VC.

4.4.10 Industrial Site, Southeast Texas (Tier 2 Demonstration)

Investigations conducted at the Industrial Site in Southeast Texas have documented a historical release southwest of the test area. The primary COCs in the groundwater include PCE, TCE, 1,1,1-TCA, 1,1,2-TCA, cis-1,2-DCE, 1,1-dichloroethane (1,1-DCA), 1,1-DCE, and VC.

4.5 INVESTIGATION LOCATIONS

4.5.1 Former Pioneer Dry Cleaner (Tier 2 Demonstration)

Groundwater from the Former Pioneer Dry Cleaner facility flows to the northwest under a near-by strip mall building. As shown in Appendix A.1, the three sampling point clusters in the demonstration were installed west of the former dry cleaning facility on the south side of the strip mall.

4.5.2 Travis AFB (Tier 2 and Tier 3 Demonstration)

Tier 2 Demonstration: Groundwater in the WIOU generally flows from north to south. Several sources of chlorinated solvent releases within this area have resulted in a heterogeneous plume with a general north-south orientation. As shown in Appendix A.2, the sample point clusters for the Tier 2 demonstration have been installed in the vicinity of Building 828.

Tier 3 Demonstration: The Tier 3 demonstration was conducted in Building 828 - a former security forces armory in the WIOU. The building was not occupied at the time of the demonstration. A building diagram is shown in Appendix A.2.

4.5.3 NAS Jacksonville (Tier 3 Demonstration)

The Tier 3 demonstration was conducted in Building 103, a machine shop located within OU3. The main portion of the building is 280 ft by 130 ft, with a secondary wing on the east side of approximately 240 ft by 60 ft. The building is slab-on-grade with a concrete foundation and was constructed in stages beginning in the 1940s.

Due to the relatively large size of the building, the investigation focused on one corner of the building, the southwest corner. This part of the building is closest to the areas of documented shallow soil gas impacts and is underlain by high levels of TCE, PCE, and degradation products in soil and groundwater (see Section 4.4.3). A building diagram is shown Appendix A.3.

4.5.4 Parris Island Marine Base (Tier 2 and Tier 3 Demonstration)

Tier 2 Demonstration: Two sample point clusters were planned for the PCE plume southeast of the new dry cleaning facility and one cluster was planned east of the former dry cleaning facility. However, during the installation of sample points at the first cluster, groundwater was encountered at a depth of 1 ft. This depth was too shallow to allow for installation of vertically-spaced sample points in the vadose zone. As a result the Tier 2 demonstration was cancelled at Parris Island.

Tier 3 Demonstration: The Tier 3 demonstration was conducted at the new dry cleaning facility. This building is 120 ft by 70 ft with a ceiling height ranging from 15 to 25 ft. When originally opened, this facility was operated as a dry cleaning facility using petroleum-based cleaning solvents (i.e., no PCE or other chlorinated solvents). However, at the time of the demonstration, on-site dry cleaning operations had been terminated and the facility was being used as a dry cleaning drop station for off-site cleaning. The off-site dry cleaner was using PCE-based cleaning solvent and, as a result, the clothing being stored on-site for customer pick-up was an indoor source of PCE. In addition, the building contained large ventilation slats in the walls along with ceiling vents that could not be completely closed. These ventilation structures were not identified during the building selection process. As a result, building pressure control could not be achieved during the demonstration. A building diagram is shown in Appendix A.4.

4.5.5 Tinker Air Force Base (Tier 2 and Tier 3 Demonstration)

Tier 2 Demonstration: Shallow groundwater near Building 201 generally flows from east to west. As shown Appendix A.5, the sample point clusters for the Tier 2 demonstration have been installed east of building 201.

Tier 3 Demonstration: The Tier 3 demonstration was conducted in the mechanical room of building 200. This building is located approximately ¼ mile from the Tier 2 demonstration site. The mechanical room is not continuously occupied and is physically isolated from the remaining portion of the building with only one door providing a connection. A building diagram is shown in Appendix A.5.

4.5.6 Hill Air Force Base (Tier 2 and Tier 3 Demonstration)

The Tier 2 and 3 demonstrations were conducted at different Operable Units (OUs) at Hill AFB. The two groundwater plumes originate from different sources and have different COCs.

Tier 2 Demonstration: Shallow groundwater within the OU5 property flows from east to west. As shown in Appendix A.6, the sample point clusters for the Tier 2 demonstration were installed near the eastern boundary between existing monitoring wells U5-1087 and U5-1086.

Tier 3 Demonstration: The Tier 3 demonstration was conducted at a building south of Hill AFB (the “ASU Research House”). This building overlies a dissolved plume of TCE and 1,1-DCE. As part of the work on ER-1686, ASU has confirmed that vapor intrusion of these compounds is occurring at this building. The floor plan of the house is shown in Appendix A.6. The building is an unoccupied single-family dwelling with a partially below-grade finished basement and a single story living space above the basement. During all testing, interior doors remained open (other than the door between the living space and garage) and windows were closed. Building egresses were not controlled and testing staff moved about freely.

4.5.7 Moffett Field NAS (Tier 3 Demonstration)

Building 107 is a single story slab-on-grade structure. The floor plan of the building is shown in Appendix A.7. The building is typically in use during normal office hours. During all testing, interior doors remained open, the fan to induce the appropriate pressure perturbation was kept running, exterior windows were closed, but building egresses were not controlled and building occupants were allowed to come and go freely.

4.5.8 SPAWAR OTC Facility (Tier 2 Demonstration)

Shallow groundwater at the SPAWAR OTC Facility flows north and northwest under Building 3. As shown in Appendix A.8, the three sampling point clusters for the Tier 2 demonstration were installed in the parking lot just southwest of Building 3 and northwest of Building 28.

4.5.9 NIKE Battery Site PR-58 (Tier 2 Demonstration)

Shallow groundwater within NIKE Battery Site PR-58 flows southeast. As shown in Appendix A.9, the three sampling point clusters for the Tier 2 demonstration were centered on existing monitoring well cluster MW03-11 approximately 125 ft northeast of the intersection of Babcock Road and Seabee Avenue.

4.5.10 Industrial Site, Southeast Texas (Tier 2 Demonstration)

Shallow groundwater at the Industrial Site in Southeast Texas flows northeast. As shown in Appendix A.10, the three sampling point clusters for the Tier 2 demonstration were installed southeast of warehouse/office buildings in an open field between existing monitoring wells MW-17 and MW-18 located near the southeast corner of the property boundary.

5.0 TEST DESIGN

This section provides the detailed description of the system design and testing conducted during the demonstrations.

5.1 CONCEPTUAL EXPERIMENTAL DESIGN

The purpose of this field demonstration is to validate i) confining layers and high moisture content fine-grained soil layers in the vadose zone as site specific criteria that support use of higher Tier 2 screening criteria for the vapor intrusion pathway, and ii) the use of building pressure gradient measurements and control of building pressure in a streamlined Tier 3 evaluation of vapor intrusion. Validation of the Tier 2 screening procedures and criteria will requires measurement of VOC attenuation at a number of sites with and without the defining characteristics (i.e., a high moisture content fine-grained soil layer in the vadose zone or serving as an aquifer confining layer) to demonstrate a difference in VOC attenuation between these types of sites. Validation of the streamlined Tier 3 evaluation methods requires application of the method at a number of buildings to demonstrate that the investigation methods provide a clear determination of vapor intrusion conditions for buildings of different size, design, and foundation characteristics.

5.1.1 Tier 2 Screening Criteria Based on Soil Conditions

The literature review and survey performed as part of this study identified the importance of high moisture content fine-grained soils as a barrier to VOC migration from groundwater to indoor air (GSI, 2008). This suggested that VOC migration from a confined aquifer to vadose-zone soils will be limited and that high moisture content fine-grained soil layers within the vadose zone would also limit the vertical migration of VOCs through the vadose zone. Field validation is likely to show consistently greater than 10x higher VOC attenuation at sites with confined aquifer conditions or high moisture content fine-grained soil layers within the vadose zone compared to sites with unconfined aquifer conditions and sandy soils.

Use of soil type and moisture content for Tier 2 screening would involve the following steps:

- Soil Type: Demonstration of confining aquifer conditions or a laterally-continuous fine-grained soil layer in the area of interest.

- Soil Moisture: Demonstration of high moisture content in the fine-grained soils either by direct measurement or by demonstration that regional climate conditions result in maintenance of high moisture contents in the fine-grained soils.

- Tier 2 Screening Criteria: Selection of appropriate Tier 2 screening criteria for groundwater or deep soil gas based on increased attenuation through the confining layer or fine-grained soil layer. The field validation program will document the magnitude of this increased attenuation and will provide the basis for a validated fact sheet documenting the screening procedures.

As illustrated in Figure 5.1.1, the impact of an aquifer confining layer or high moisture content fine-grained soil layer on VOC attenuation will be validated through the measurement of aquifer confining conditions, soil parameters, and VOC concentrations at eight demonstration sites. The demonstration sites represent a range of confined and unconfined aquifer conditions in order to clearly document the differences in VOC attenuation between sites. The sampling program for the validation of the Tier 2 screening procedure is summarized in Table 5.1.1 and the field schedule is provided in Figure 5.1.2.

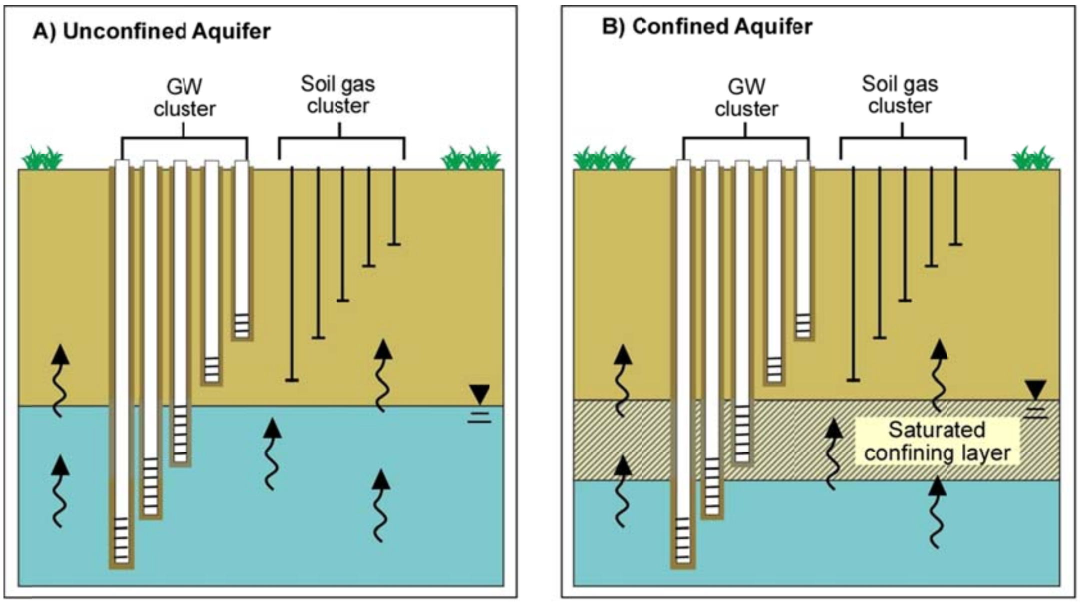

Figure 5.1.1: Conceptual plan for field validation of soil type and moisture content as basis for selection of Tier 2 vapor intrusion screening criteria.

Table 5.1.1: Summary of Tier 2 Evaluation Sampling Program

Component	Matrix	Number of Samples	Analyte	Location
Validation of Tier 2 Screening Procedures and Criteria: Sample Program for Each Demonstration Site	Soil	2 - 4	Soil Permeability (Field Test)	Each groundwater sample point without water from each of 3 clusters
	Soil	12	Physical properties	4 soil intervals from each of 3 clusters
	Groundwater	9	VOCs	Each sample point with groundwater (3 clusters)
	Leak tracer (for each soil gas point)	15	SF_6	Each soil gas sample point (3 clusters)
	Soil gas	15	VOCs	Each soil gas sample point (3 clusters)

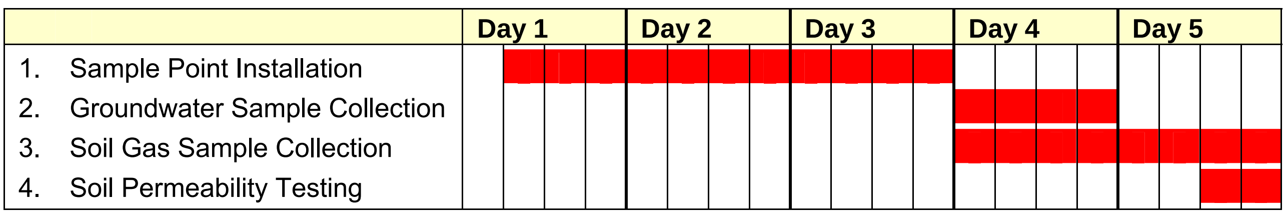

Figure 5.1.2: Field Schedule for Tier 2 Demonstration Program

5.1.2 Streamlined Tier 3 Evaluation Based on Building Foundation Permeability

Although building foundation permeability has been identified as an important site characteristic for vapor intrusion, the peer-reviewed literature and regulatory guidance do not provide accepted methods for the evaluation of foundation permeability. In order to support expedited Tier 3 field evaluations of individual buildings, the field program will include validation of i) a method to evaluate building foundation permeability by measuring pressure gradients across the foundation and comparing to pressure gradients across the building envelope, and ii) a streamlined sampling program to evaluate the potential for vapor intrusion under a range of building pressure conditions at a building through a single sampling event.

Use of foundation permeability for an expedited Tier 3 field evaluation would involve the following steps:

- Measurement of Foundation Permeability: Determine foundation permeability based on measurement of pressures indoors, outdoors, and in below-foundation soils during induced building pressurization and depressurization. At buildings with permeable foundations, building pressure will be efficiently transferred to underlying soils. At buildings with low permeability foundations, high cross-foundation pressure gradients will be measured.

The use of pressure gradient measurements to evaluate building foundation permeability is applicable to solid foundations that provide some measurable resistance to airflow (e.g., concrete foundations). This measurement method is not applicable to buildings with pier and beam foundations, which typically have an unfinished crawl space below the lowest floor.

- Measurement of "Worst Case" Attenuation Factors: Measure VOC and radon concentrations at below-foundation sample points and in indoor air during an induced building depressurization event to evaluate VOC attenuation under "worst case" conditions and during an induced positive pressure event.

- Vapor Intrusion Determination: Based on the combined understanding of foundation permeability and "worst-case" cross-foundation attenuation, the potential for current and future vapor intrusion impacts to a building is determined in a single sampling event.

The impact of building pressure on vapor intrusion is illustrated in Figure 5.1.3. The sampling program for the validation of the streamlined Tier 3 evaluation procedure is summarized in Table 5.1.2 and the field schedule is provided in Figure 5.1.4.

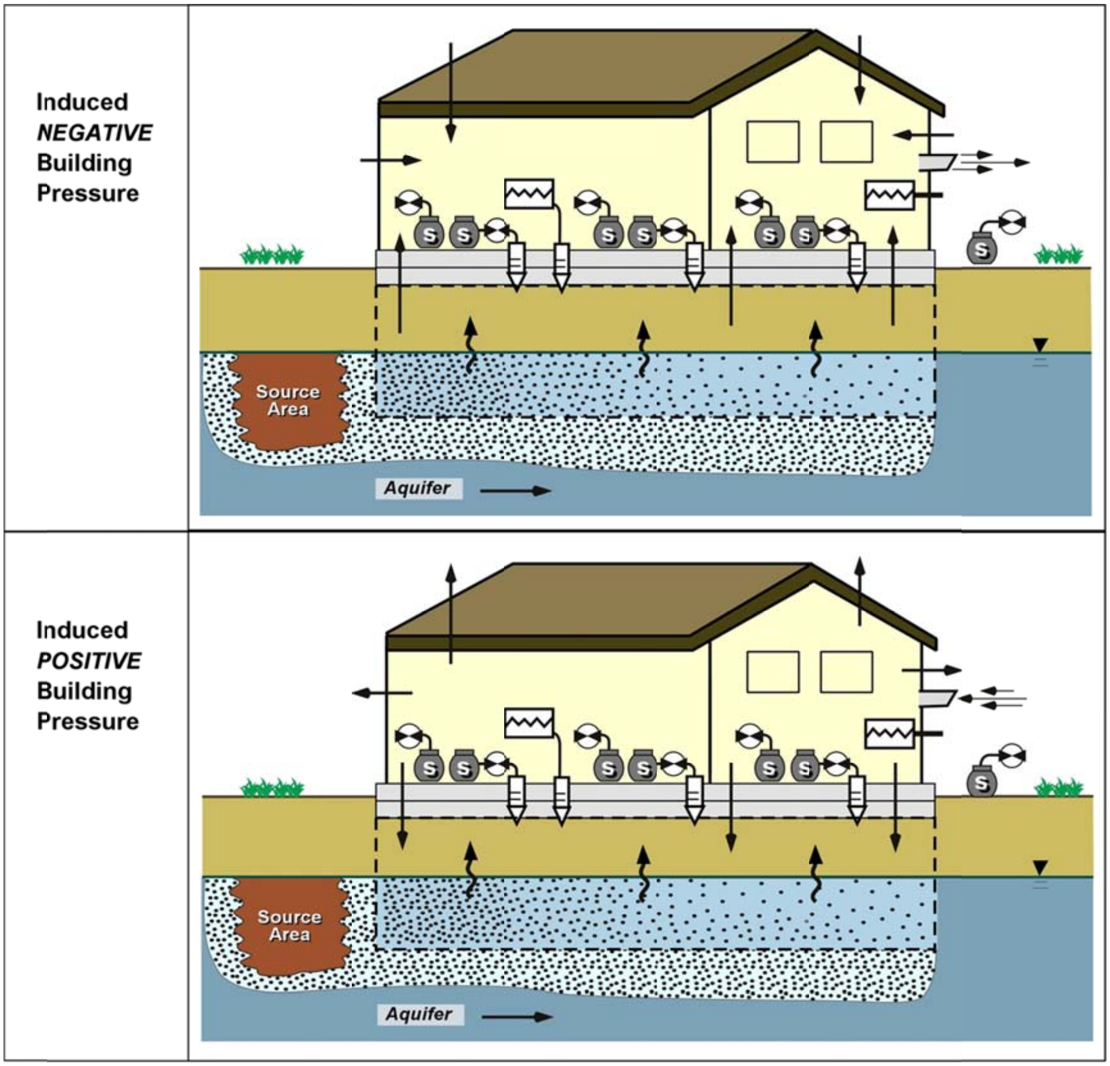

Figure 5.1.3: Conceptual basis for measurement of foundation permeability as part of expedited Tier 3 evaluation of vapor intrusion.

Table 5.1.2: Summary of Tier 3 Evaluation Sampling Program

Component	Matrix	Number of Samples	Analyte	Location
Tier 3 Building Investigation (each test building)	Indoor air	6	Radon, SF_6, VOCs	Indoors, 3 locations (negative pressure and positive pressure events)
	Sub slab vapor	6	Radon, SF_6, VOCs	Sub-slab, 3 locations (negative pressure and positive pressure events)
	Ambient air	1	Radon, SF_6, VOCs	Outdoors, upgradient, once at each location
	Pressure Gradient	NA	Differential pressure between indoor/outdoor and indoor/sub slab space	Continuous sampling at various sample points during positive and negative pressure conditions

Note: Additional samples collected for some demonstrations.

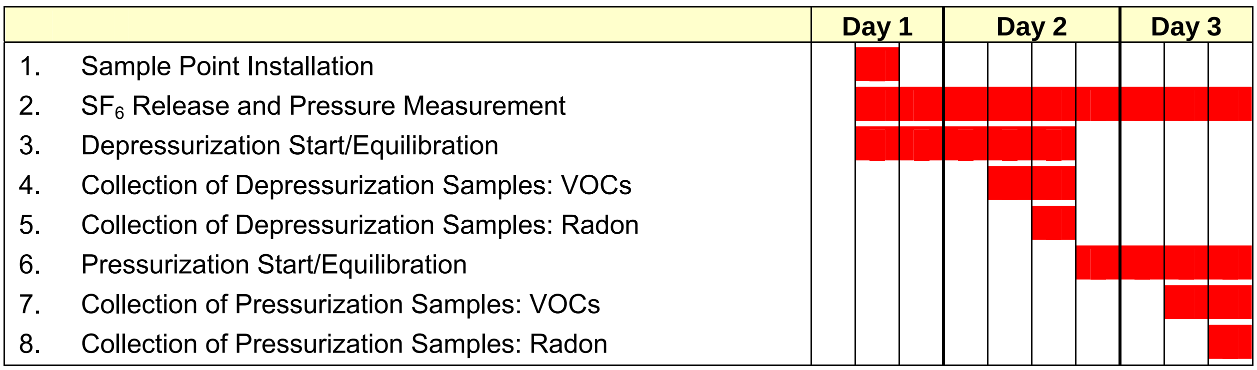

Figure 5.1.4: Tier 3 Field Testing Schedule

5.2 BASELINE CHARACTERIZATION

As discussed in Section 4, each of the field demonstration sites has been characterized through prior site investigations that have included the installation of several soil borings and monitoring wells. These investigations provided an understanding of the shallow geology and the distribution of site contaminants that was sufficient to support the design and implementation of the demonstration program at each site. As a result, no additional baseline characterization activities were conducted prior to the field demonstration at each site.

5.3 TREATABILITY OR LABORATORY STUDY RESULTS

No treatability or laboratory confirmation studies were conducted for this demonstration.

5.4 DESIGN AND LAYOUT OF TECHNOLOGY COMPONENTS

At each candidate site selected for the Tier 2 or Tier 3 site investigation field demonstration, the field program consisted of i) installation of sampling points and collection of soil samples for geotechnical testing, and ii) field testing and collection of water and/or gas samples. Section 5.4 describes the procedures used for installation of the sampling points and Sections 5.5 and 5.6 describe the field testing and sample collection and analysis methods, respectively.

5.4.1 Installation of Sampling Points for Evaluation of Tier 2 Screening Procedure

At each site selected for the Tier 2 demonstration, three clusters of sample points were installed for groundwater and soil gas sampling. Each cluster consists of five 1-inch PVC sample points and five 1/8-inch Nylaflow tubing sample points. Three of the five PVC points were targeted at depths at or below the water table and the other two were targeted at short distances above the water table. The Nylaflow sample points were spaced through the vadose zone starting just above the water table.

<u>1-inch PVC (Groundwater) Sampling Points:</u> A total of five temporary piezometers were installed at each cluster for groundwater sampling using traditional direct-push techniques. Using a truck-mounted Geoprobe® or drilling rig, the first location at each cluster was advanced to the shallow groundwater bearing unit (GWBU). Soil cores were continuously collected and logged in accordance with the Unified Soil Classification System (USCS). The installation depths were determined based on prior site characterization and the geology observed during sample point installation. For confined aquifer sites, the deepest well screen was installed just below the top of the shallowest GWBU. Once the first temporary well was completed, depth-to-water (DTW) measurements were collected and compared with historical DTW measurements at nearby wells to determine the local potentiometric surface. The second and third temporary piezometers were installed mid-way between the shallow GWBU and the potentiometric surface and just below the potentiometric surface, respectively. The remaining two temporary piezometers were installed at two vertically spaced depths just above the potentiometric surface. For sites with unconfined aquifer conditions, the temporary piezometers were installed so that the middle piezometer was at the top of the GWBU and the other points were installed above and below this point with 1 to 2 ft of vertical spacing. The installation of two 1-inch PVC sample points at depths above the potentiometric surface served to i) account for uncertainty in the exact depth of groundwater, and ii) allow for field measurement of vadose zone permeability in dry sample points. Representative undisturbed soil samples were collected from the second temporary piezometer for geotechnical analysis, as described below. The remaining three temporary piezometers locations were advanced with no sample collection or logging.

Temporary piezometers were constructed of one inch schedule 40 PVC pipe with flush threaded joints. The well screens consist of 6 inches of number ten slotted PVC with a threaded cap on the bottom with no sump. The screened interval of the well was packed with U.S. mesh interval 20/40 sand approximately one to two feet above the top of the screen. The remainder of the borehole was filled with bentonite chips to the ground surface and hydrated to create an annular seal. Upon completion, temporary wells were capped with a tight fitting PVC slip cap. Temporary wells were then completed at the surface using a 6-inch steel flush mount man-way secured with concrete. An example of an uncompleted cluster is shown in Photo 5.4.1 and example temporary piezometer construction specifications are shown on Figure 5.4.1. Specific screen intervals for each cluster are presented in the site data packages included as Appendix A.

Photo 5.4.1: Example Soil Gas and Temporary Well Cluster (Travis AFB)

<u>1/8-Inch Nylaflow (Soil Gas) Sampling Points:</u> A total of five soil gas points were installed at each cluster using traditional direct-push techniques. Based on the vertical distribution of the five temporary piezometers, the five soil gas points in each cluster were vertically spaced within the vadose zone between the potentiometric surface and the ground surface. The two deepest soil gas points were installed at the same depth as the two shallowest 1-inch PVC sample points and the three remaining points were vertically spaced through the vadose zone. All five soil gas sampling points were advanced with no sample collection or logging.

The soil gas sampling points were constructed of stainless steel vapor implant points attached securely to 1/8-inch Nylaflow tubing and lowered to the bottom of the borehole. An example of the stainless steel vapor implant point and 1/8-inch Nylaflow tubing is shown in Photo 5.4.2. A sand pack using U.S. mesh interval 20/40 sand was installed to approximately 6-inches above the vapor implant point. The remainder of the borehole was filled with bentonite chips to the ground surface and hydrated to create an annular seal. Upon completion, the 1/8-inch Nylaflow tubing was sealed from atmospheric air with modeling clay. To protect the Nylaflow tubing, the tubing was encased within approximately 1-foot of schedule 40 PVC pipe at the surface, capped with a tight fitting PVC slip cap, and then completed using a 6-inch steel, flush mount man-way, individually installed with concrete pads. An example of the soil gas sampling point construction specifications is shown on Figure 5.4.1.

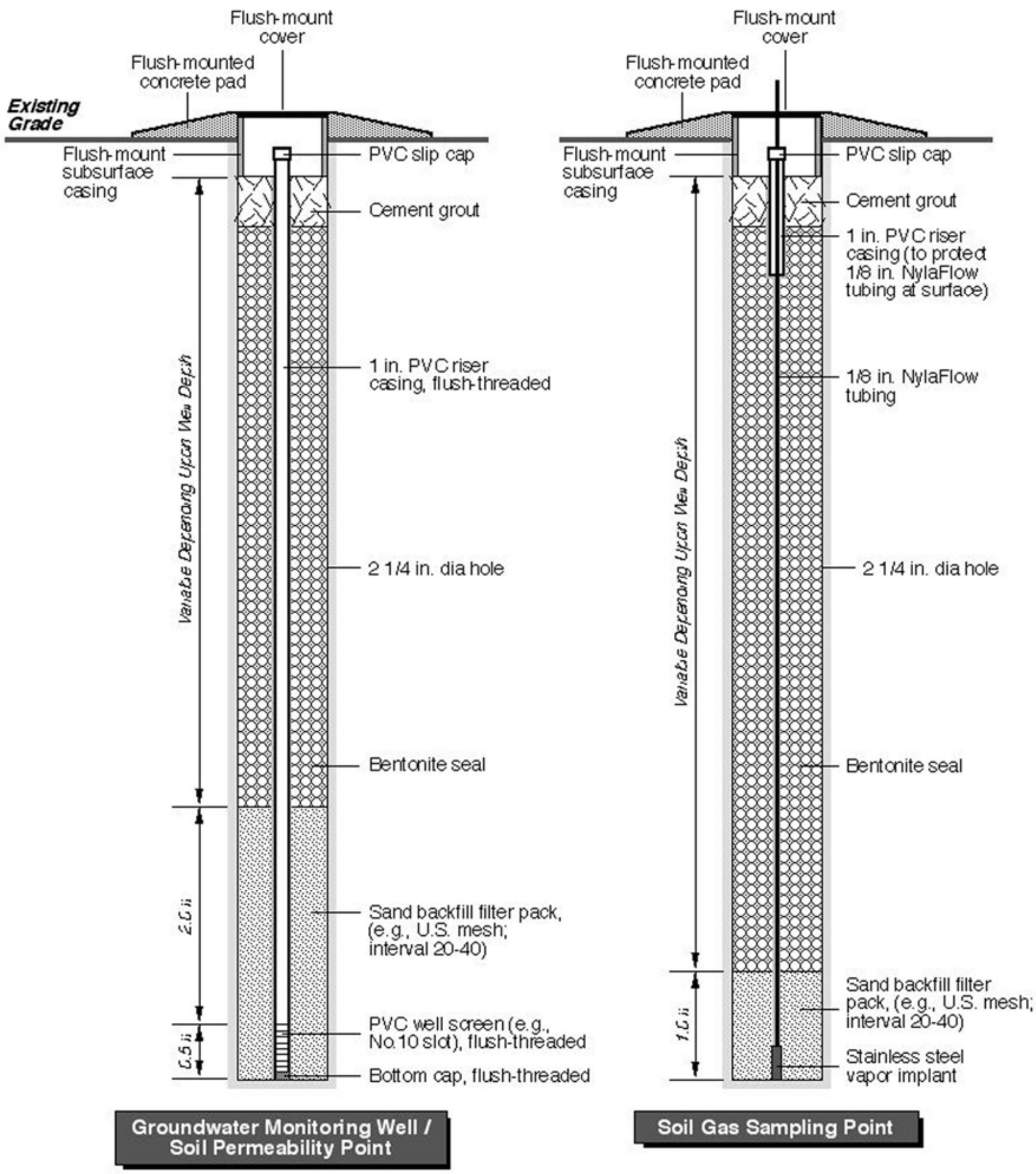

Figure 5.4.1: Construction Specifications for Groundwater and Soil Gas Sampling Points

Photo 5.4.2: Example Soil Gas Sampling Implant

5.4.2 Installation of Sampling Points for Validation of Tier 3 Investigation Program

Sub-slab Sample Points: At each building selected for the Tier 3 demonstration, several sub-slab sample points were installed below the concrete slab using a hammer rotary drill with a 1-inch drill bit. Most sample points were completed just below the slab; however, one or more deeper holes were advanced at each site using a ¾-inch steel rod driven to a depth of 30 inches bgs. The sub-slab sampling points were constructed of 1/8- or ¼-inch Nylaflow tubing lowered to the bottom of the borehole. A sand pack using U.S. mesh interval 20/40 sand was installed a few inches above the bottom of the borehole. The remainder of the borehole was filled with bentonite chips to the ground surface and hydrated to create an annular seal. Upon completion, the top of the borehole and the Nylaflow tubing were sealed from atmospheric air with modeling clay. An example of a completed sub-slab sampling point is shown in Photo 5.4.3 and the sub-slab sampling point construction specifications are shown on Figure 5.4.2.

Photo 5.4.3: Example Sub-Slab Sample Port and Sample Train

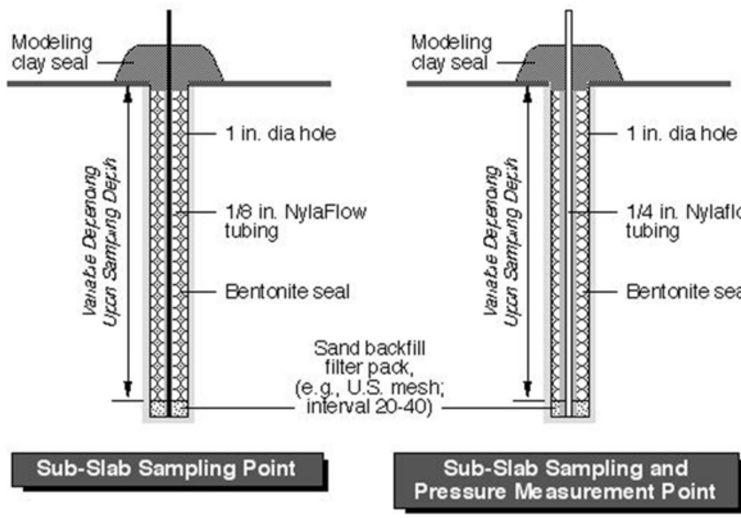

Figure 5.4.2: Construction Specifications for Sub-Slab Sampling Points

Indoor Sample Points: For each test building, three indoor air sample points were selected to characterize the distribution of VOCs, radon, and SF_6 tracer gas inside the building. Specific sample points were selected based on evaluation of building operating characteristics and were located to minimize the disturbance of building activities.

Outdoor Sample Point: For each test building, one air sample point was selected to characterize the concentration of VOCs, radon, and SF_6 tracer gas outside the building. The specific sample point was selected at an upwind location based on evaluation of building operating characteristics and current wind direction.

Building Envelope Pressure Gradient Measurement Points: For each test building, one or more points were identified to measure the pressure gradient across the building envelope (i.e., ambient/indoor pressure gradient). At each measurement point, ¼ inch tubing was installed across the building envelope to allow measurement of the pressure gradient using a portable pressure transducer.

5.5 FIELD TESTING

One round of field testing and sample collection was conducted at each demonstration site following installation of the sampling points. The field testing program for the validation of the Tier 2 and Tier 3 procedures is described below.

5.5.1 Field Testing for Evaluation of Tier 2 Screening Procedure

For validation of the Tier 2 screening procedure, the field testing program consisted of measurements of soil permeability from the soil gas sampling points.

Following collection of soil gas samples (Section 5.6.1), the permeability of the vadose zone soils was measured at each 1-inch PVC point without measureable water. Permeability was determined using a vacuum pump and flow meter. Soil gas was extracted by applying a vacuum to the soil gas monitoring point, and the resulting flow measured using laboratory-grade flow meters. The steady state vacuum was measured at least at three different flow rates at each sample point, and the soil permeability determined by the relationship between the flow rate and vacuum (Photo 5.5.1). This procedure (measurement of flow and vacuum at a single point) provides a semi-quantitative measurement of vadose zone permeability that was used as a supplement to the laboratory geotechnical analysis of soil cores. Procedures for calculation of soil permeability are provided in Appendix C.

Photo 5.5.1: Soil Permeability Measurement

5.5.2 Field Testing of Tier 3 Evaluation Procedure

For validation of the Tier 3 evaluation procedure, the field testing program consists of the measurement of cross-foundation and building envelope pressure gradients.

Measurement of Pressure Gradients: Pressure gradients across the building foundation compared to pressure gradients across the building envelope are used to evaluate the building foundation permeability. Pressure gradients were measured using an Omniguard 4 differential pressure transducer, which is equipped with a data logger. The pressure transducer has 2 pressure ports, a reference port open to the indoor atmosphere, and a second port that is open to the area to be measured (sub slab space or outside the building). The pressure transducer measures the pressure difference between the two ports, providing a differential pressure measurement. A photo of the pressure transducer installation is presented in Photo 5.5.2.

At the initiation of the testing program, the pressure gradient was measured at each sub-slab measurement point and at the building envelope pressure gradient measurement point. Pressure gradients at each measurement location were recorded for a period of at least one minute. During the collection of the composite samples for VOC analysis, continuous pressure gradient measurements were recorded at one cross-foundation measurement point located near the center of the building and at one building envelope measurement point.

Photo 5.5.2: Pressure transducer installation

5.6 SAMPLING METHODS

Sampling methods for the Tier 2 and 3 demonstrations are described below. Analytical methods for applicable media sampled under either tier are summarized in Table 5.6.1.

Table 5.6.1: Analytical Methods Used for Sample Analysis

Matrix	Analyte	Method	Container	Preservative	Holding Time
Soil	Intrinsic Permeability	API RP 40/ ASTM D2434	Undisturbed core	None	None
	Porosity, total and air-filled	API RP 40	Undisturbed core	None	None
	Dry bulk density	API RP 40/ASTM D4564/ASTM D2937	Undisturbed core	None	None
	Volumetric moisture content	ASTM DD216/ASTM D4959/ASTM D4643	Undisturbed core	None	None
	Fraction organic carbon	Walkley-Black, EPA 9060	Undisturbed core	None	None
Ground-water	VOCs	US EPA 8260B	40 ml VOA vial	HCl	14 days
Vapor	Radon	McHugh et al., 2008	500 ml Tedlar bag	None	14 days*
	Chlorinated VOCs	US EPA TO-15	500 ml Tedlar bag or 1L Summa Can	None	28 days
	SF_6	NIOSH 6602	500 ml Tedlar bag or 1L Summa Can	None	28 days

* = No holding time specified, but lab tests demonstrate accurate results after 14 days storage in Tedlar bag (McHugh et al., 2008).

5.6.1 Sampling Methods for Validation of Tier 2 Screening Procedure

Validation of the Tier 2 screening procedure will involve collection and analysis of soil samples for geotechnical analysis and groundwater and soil gas samples for analysis of VOC concentrations.

Collection and Analysis of Soil Geotechnical Samples: Geotechnical samples were collected during the temporary piezometer installation from the second deepest borehole at each cluster. One-foot soil core samples were collected from the three clusters. Sampling depths for the geotechnical samples were vertically distributed to cover the variation in lithology observed in the deepest boring previously collected from that location. Samples were collected by retaining the undisturbed soils in the plastic sleeve used in boring advancement, cutting out the desired depth interval, capping the ends with different color caps to differentiate the top from the bottom, and then sealing with duct tape to ensure an air-tight seal. The number of samples collected for each demonstration is provided in Table 5.1.1 and the analytical methods are provided in Table 5.6.1 above.

Geotechnical soil samples were analyzed for dry bulk density, fraction organic carbon, volumetric moisture content, total and air-filled porosity, intrinsic permeability, and native hydraulic conductivity. Geotechnical analyses were performed by Fugro Consultants, Inc. in Houston, Texas, according to applicable American Society for Testing and Materials (ASTM), EPA, and American Petroleum Institute (API) methods as outlined in the QAPP included with the demonstration plan.

Collection and Analysis of Groundwater Samples: Prior to sampling, all groundwater sampling points were gauged to determine whether groundwater had infiltrated the well and to measure the static water level. Temporary piezometers with groundwater infiltration were then pumped using a low-flow peristaltic pump until i) more than three casing volumes of water had been removed from the sample point, ii) clear water (free of silt) was obtained, or iii) the sample point was pumped dry. If the sample point was pumped dry, the point was allowed to recharge prior to sampling within 24 hours. Groundwater was collected using the peristaltic pump, placed in method-specific containers, placed on ice, and shipped to an environmental laboratory under chain-of-custody control for the analysis of VOCs using USEPA Method SW846 8260B. Duplicate samples were collected at the greater frequency of one per event or one per every ten samples. During the sampling event, physical properties such as temperature, specific conductance, and pH were measured if there was sufficient sample volume. The number of samples collected for each demonstration is provided in Table 5.1.1 and the analytical methods are provided in Table 5.6.1 above.

Collection and Analysis of Soil Gas Samples: Soil gas samples were collected from 1/8-inch or ¼-inch Nylaflow sample point. Gas samples were then collected in 1L Summa Canisters or 0.5-L Tedlar bags using 60 mL gas-tight syringes, equipped with a 3-way valves. 1L Summa Canisters were used at sites or sample points with higher permeability soils that supported the collection of larger sample volumes. 0.5-L Tedlar bags were used for sample points where soil conditions limited the sample collection volume. During soil gas sampling, sulfur hexafluoride (SF_6) gas was released within a shroud over each soil gas sampling point. SF_6 was used as a tracer gas to determine if any leaks were present in the sampling point. The sample containers were then shipped within 24 hours to Columbia Analytical Services, Inc. under chain-of-custody control. Samples collected into Tedlar bags were analyzed within 48 hours of sample collection. Soil gas samples were analyzed for: i) VOCs by Method TO-15 Modified, and ii) SF_6 by National Institute for Occupational Safety and Health (NIOSH) Method 6602 Modified. The number of samples collected for each demonstration is provided in Table 5.1.1 and the analytical methods are provided in Table 5.6.1 above. The sample train used for sample collection is illustrated below in Figure 5.6.1.

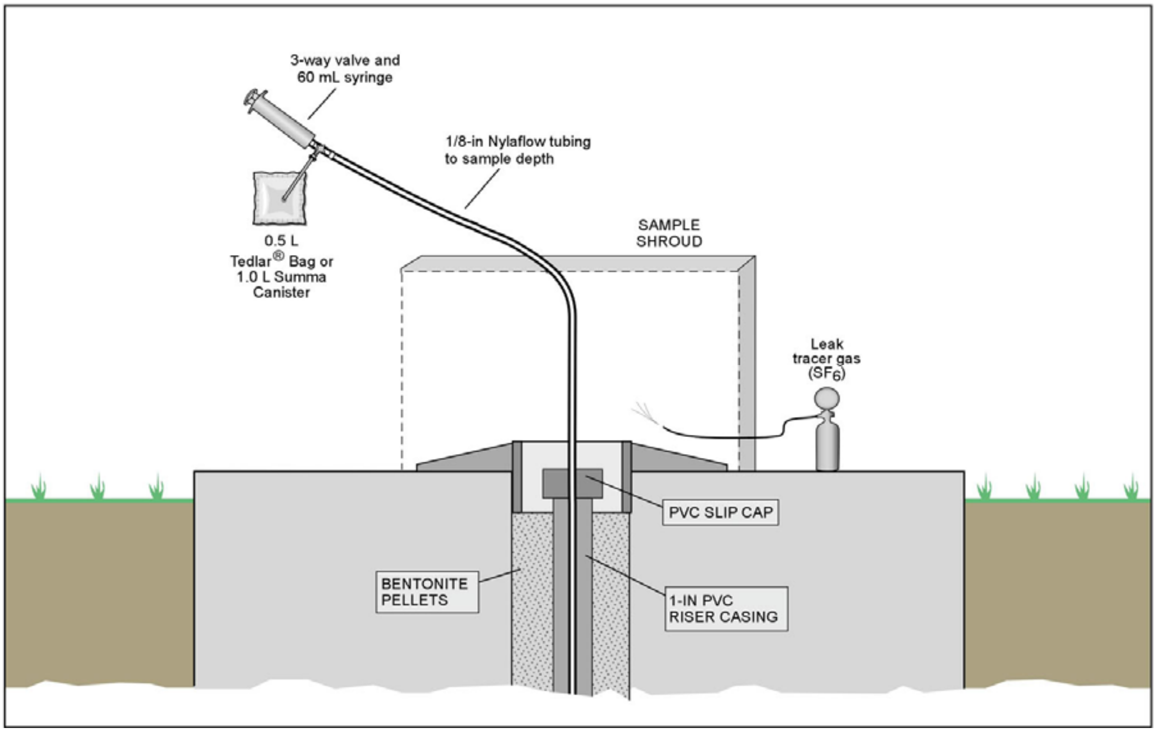

Figure 5.6.1: Collection of Soil Gas Samples for Tier 2 Demonstration

5.6.2 Sampling Methods for Validation of Tier 3 Evaluation Procedure

Validation of the Tier 3 evaluation procedure involved collection and analysis of indoor air, ambient air, and sub-slab soil gas samples under negative pressure and positive pressure building conditions.

Induction of Negative and Positive Building Pressure: Negative and positive building pressures were created using a box fan in an outside window or door. The resulting pressure gradients were recorded as described in Section 5.5. Negative and positive pressure conditions were maintained for 12 hours prior to initiation of sample collection to allow the chemical concentrations to reach steady state.

Measurement of Building Air Exchange Rate: For 7 of the 8 demonstrations, a tracer gas, SF_6, was used to evaluate the indoor air exchange rate (i.e., the rate of air exchange between the building and ambient air). The indoor air exchange rate was measured by releasing SF_6 at a central location within the building and measuring steady-state SF_6 concentration at each indoor air sample location after 12 or more hours. The SF_6 release system is shown in Photo 5.6.1. At Tinker AFB Building 200, no tracer gas was used due to an error in obtaining the correct gas. In all buildings, the volume of air flow induced by the fan was calculated in order to provide an estimate of air exchange attributable to the pressure control system.

Photo 5.6.1: SF_6 Tracer Gas Release System

Collection and Analysis of Indoor and Ambient Air Samples: At each test building, indoor air samples were collected at three locations. At each location, a 6L Summa canister was used to collect an 8-hour composite sample for analysis of VOCs and SF_6. A Tedlar bag was used to collect a grab sample for radon analysis. This sampling program was completed once during the negative pressure event and once during the positive pressure event.

At each test building, an ambient air sample was collected outside of the test building during each indoor air sampling event to serve as an ambient background sample. One sample 8-hour composite was collected for analysis of VOCs and SF_6 using a 6L Summa canister, and one grab sample was collected using a Tedlar bag for radon analysis.

At the ASU Research House, a HAPSITE portable GC/MS was used to collect and analyze supplemental indoor air samples. For this demonstration, 126 supplemental indoor air samples were collected from indoor air sample location IA-2 and analyzed for TCE and 1,1-DCE.

Collection and Analysis of Sub-Slab Gas Samples: At each test building, each of the three sub-slab sampling points was sampled during the two sampling events (i.e., negative building pressure and positive building pressure). At each location, a 1L Summa canister was used to collect a grab sample for analysis of VOCs and SF_6. A Tedlar bag was used to collect a grab sample for radon analysis. The number of samples collected for each demonstration is provided in Table 5.1.2 and the analytical methods are provided in Table 5.6.1 above. The sample train used for sample collection is illustrated below in Figure 5.6.2.

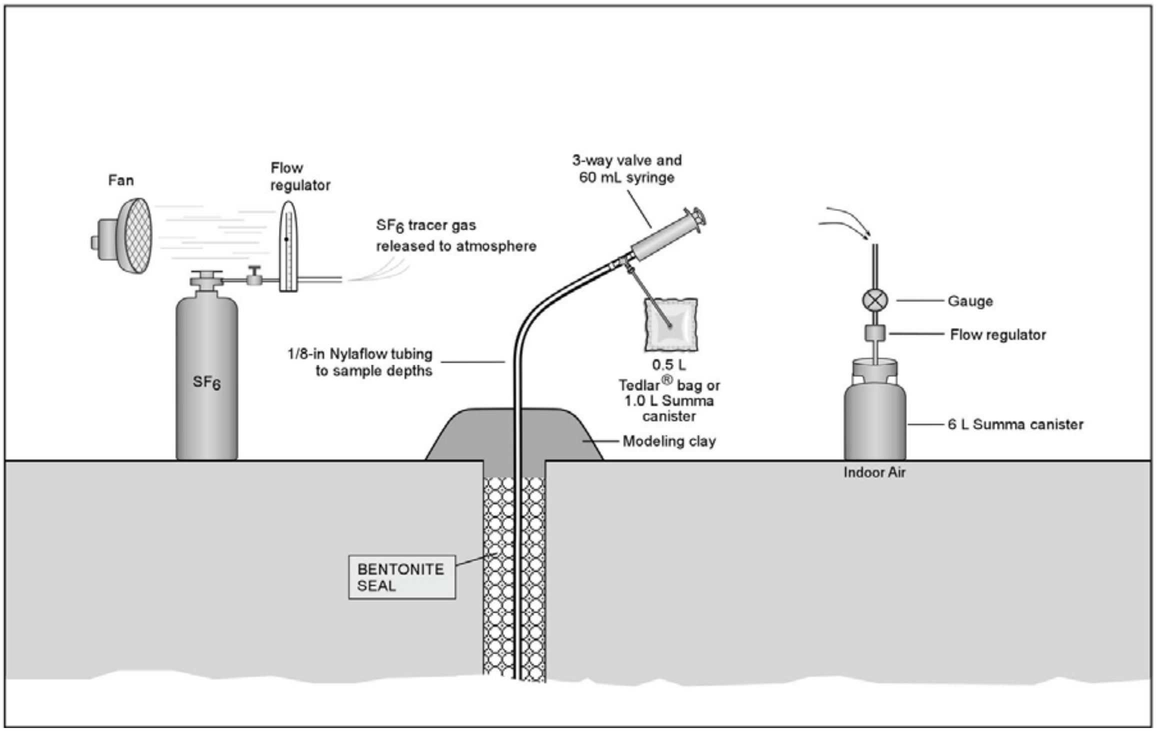

Figure 5.6.2: Collection of Indoor and Sub-slab Samples for Tier 3 Demonstration

5.7 SAMPLING RESULTS

Comprehensive sampling results for each site included in the Tier 2 and Tier 3 demonstrations are provided in Appendix A. Original laboratory reports are provided in Appendix D. The results are summarized in this section in sufficient detail to support the performance assessment presented in Section 6.

5.7.1 Validation of Tier 2 Screening Criteria and Procedures

As discussed in Section 6.1, the Tier 2 demonstration was completed at seven sites. The demonstration was planned but not completed at an eighth site due to unexpectedly shallow groundwater.

As discussed in Section 5.4.1, three clusters of five vertically-spaced temporary piezometers and five vertically-spaced soil gas sampling points were installed at each demonstration site. The goal was to install the middle piezometer at the top of the water-bearing unit so that three piezometers would have water and two would be completed in the vadose zone. Recognizing the difficulty in identifying the exact depth of the top of the water-bearing zone, the program was designed to ensure that a minimum of two and a maximum of four piezometers were completed within the water-bearing zone. The deepest two soil gas points were installed at the same depth as the shallowest two piezometers (see Figure 5.1.1) and the three shallower soil gas points were installed at shallower depths using 1 to 2 ft vertical spacing.

Water samples were collected from all piezometers that yielded water and field soil permeability tests were conducted at all piezometers that did not yield water. Soil gas samples were collected from all soil gas points that did not yield water during attempted sample collection. The resulting sampling program for each demonstration site is summarized in Table 5.7.1.

Table 5.7.1: Summary of Sampling Program for Each Tier 2 Demonstration Site

Site	Groundwater Samples	Soil Gas Samples	Field Soil Permeability Tests	Soil Cores for Analysis of Physical Properties
Pioneer Cleaners	12	9	3	13
Travis AFB	9	15	6	11
Tinker AFB	10	10	4	8
SPAWAR OTC	9	12	5	14
NIKE Site	8	12	6	11
Hill AFB	9	15	6	15
SE Texas Industrial Site	8	15	7	13

5.7.2 Validation of Streamlined Tier 3 Evaluation Procedures

As discussed in Section 6.3, the Tier 3 demonstration was completed in six buildings. The scope of each demonstration is summarized in Table 5.7.2. In four buildings, testing was conducted under controlled negative and positive pressure conditions. For the remaining two buildings, testing was conducted under baseline (i.e., uncontrolled pressure) and controlled negative and positive pressure conditions. In accordance with the Demonstration Plan Addendum, the testing in the last two buildings was conducted twice in order to evaluate the reproducibility of the method.

Table 5.7.2: Summary of Testing Program at Each Tier 3 Demonstration Site

Demonstration Building	Pressure Conditions Tested	Number of Testing Events
Building 828, Travis AFB	Controlled Negative Pressure Controlled Positive Pressure	One
Building 103, Jacksonville NAS	Controlled Negative Pressure Controlled Positive Pressure	One
Parris Island New Dry Cleaner Facility	Controlled Negative Pressure Controlled Positive Pressure	One
Building 102, Tinker AFB	Controlled Negative Pressure Controlled Positive Pressure	One
ASU Research House, Hill AFB	Baseline (i.e., Uncontrolled Pressure) Controlled Negative Pressure Controlled Positive Pressure	Two
Building 107, Moffett Field	Baseline (i.e., Uncontrolled Pressure) Controlled Negative Pressure Controlled Positive Pressure	Two

5.7.2.1 Air Exchange Rate: For each demonstration building, the air exchange rate was determined based on the SF_6 release rate and the concentration of SF_6 measured in indoor air. No indoor air tracer was used for the Tinker AFB demonstration due to an error in obtaining the correct tracer gas. As a result, air exchange rates could not be calculated for this building. Calculation methods are provided in Appendix B and the results are summarized in Table 5.7.3.

Table 5.7.3: Building Air Exchange Rates (day^{-1})

Demonstration Building	Baseline	Negative Pressure	Positive Pressure
Building 828, Travis AFB	NM	49 day^{-1}	80 day^{-1}
Building 103, Jacksonville NAS	NM	15 day^{-1}	14 day^{-1}
Parris Island New Dry Cleaner Facility	NM	35 day^{-1}	32 day^{-1}
Building 102, Tinker AFB	NM	NM	NM
ASU Research House, Hill AFB (Round 1)	2.4 day^{-1}	20 day^{-1}	14 day^{-1}
ASU Research House, Hill AFB (Round 2)	4.3 day^{-1}	29 day^{-1}	26 day^{-1}
Building 107, Moffett Field (Round 1)	10 day^{-1}	62 day^{-1}	42 day^{-1}
Building 107, Moffett Field (Round 2)	8.2 day^{-1}	48 day^{-1}	51 day^{-1}

NM = Not measured, tracer gas not available.

The air exchange rate under controlled pressure conditions (either negative or positive) was 5 to 7 times higher than baseline conditions where measured (see Table 5.7.3).

For the demonstrations, air exchange rates were comparable between the negative pressure test condition and the positive pressure test condition. The median change in air exchange between the two controlled pressure conditions was 16% and the maximum change was 63% for Travis AFB Building 838).

For a building where the air exchange is higher under the positive pressure condition compare to the negative pressure condition, a decrease in VOC concentration during the positive pressure condition could be attributable to either i) the increased air exchange rate, or ii) the suppression of vapor intrusion by the positive pressure condition. The air exchange rate was higher under positive pressure conditions for only two of the demonstrations: Travis AFB Building 838 (63% increase) and Moffett Field Building 107 (6% increase). For Travis AFB Building 838, the air exchange rate increased by 63% between the negative pressure and positive pressure measurement events. If the change in air exchange rate were the only factor affecting the change in VOC concentration then the expected concentration under positive pressure conditions would be as follows:

Predicted C_{pp} = Measured C_{np} x (AER_{np}/AER_{pp})

Where:

Predicted C_{pp} = Predicted chemical concentration under positive pressure conditions

Measured C_{np} = Measured chemical concentration under negative pressure conditions

AER_{pp} = Air exchange rate under positive pressure conditions

AER_{np} = Air exchange rate under negative pressure conditions

Table 5.7.4: Predicted vs. Measured Chemical Concentrations at Building 828
Under Positive Pressure Conditions

Chemical	Measured C_{np}	Predicted* C_{pp}	Measured C_{pp}
TCE	0.15 +/- 0.081 μg/m^3	0.092 μg/m^3	<0.036 +/- 0.003 μg/m^3
Radon	0.67 +/- 0.058 pCi/L	0.41 pCi/L	0.27 +/- 0.058 pCi/L

* = predicted concentration is the change if the air exchange rate were the only factor affecting concentration. Note: This calculation does not apply to VOCs with exclusively ambient sources (i.e., benzene and toluene)

The analysis summarized in Table 5.7.4 above indicates that the change in air exchange rates was not the primary cause of the change in chemical concentration in indoor air between the two sample events.

Taken as a whole, the evaluation of building air exchange rate under controlled negative and positive conditions indicates that differences in air exchange rate are typically not a significant contributor to changes in VOC concentrations measured in indoor air between the two controlled pressure conditions.

5.7.2.2 Chemical Concentrations: For each demonstration building, chemical concentrations were measured at sub-slab sample points (three locations), indoor air (three locations), and ambient air (one location). The measured concentrations are summarized in Table 5.7.5. In addition, the results of supplemental sampling and analysis conducted at the ASU Research House using the field portable HAPSITE GC/MS are provided in Appendix A.6.

Table 5.7.5: Chemical Concentrations in Demonstration Buildings

		Baseline Pressure			Negative Pressure			Positive Pressure		
		Sub-slab	Indoor Air	Ambient Air	Sub-slab	Indoor Air	Ambient Air	Sub-slab	Indoor Air	Ambient Air
Building 828, Travis AFB										
Benzene (ug/m^3)	Above ground	NM	NM	NM	0.43 +/- 0.036	0.60 +/- 0.11	0.70	< 0.41 +/- 0.006	0.54 +/- 0.061	0.50
Toluene (ug/m^3)	Above ground	NM	NM	NM	< 2.03 +/- 0.058	1.23 +/-0.37	1.30	< 2.03 +/- 0.058	0.77 +/- 0.14	0.53
SF_6 (ug/m^3)	Above ground	NM	NM	NM	< 9.75 +/- 0.13	92 +/- 17	< 8.9	10.2 +/- 0.72	56 +/- 42	< 9.1
TCE (ug/m^3)	Subsurface	NM	NM	NM	1.17 +/- 1.3	0.15 +/- 0.081	< 0.038	1.07 +/- 1.15	< 0.036 +/- 0.003	< 0.037
Radon (pCi/L)	Subsurface	NM	NM	NM	978 +/- 248	0.67 +/- 0.058	0.4	971 +/- 140	***0.27 +/- 0.058***	0.3
Building 103, Jacksonville NAS										
Benzene (ug/m^3)	Above ground	NM	NM	NM	< 23 +/- 12	0.57 +/- 0.021	0.63	< 22 +/- 11	***0.73 +/- 0.015***	0.56
Toluene (ug/m^3)	Above ground	NM	NM	NM	< 115 +/- 57	3.22 +/- 0.55	2.10	< 109 +/- 56	4.23 +/- 1.4	1.50
SF_6 (ug/m^3)	Above ground	NM	NM	NM	12 +/- 3.7	158 +/- 140	9.2	21 +/- 13	170 +/- 100	9.4
PCE (ug/m^3)	Subsurface	NM	NM	NM	19,700 +/- 9,300	1.67 +/- 0.25	0.15	19,333 +/- 8,100	***0.74 +/- 0.20***	0.14
TCE (ug/m^3)	Subsurface	NM	NM	NM	3,050 +/- 1,300	0.38 +/- 0.080	0.12	2,633 +/- 780	0.23 +/- 0.06	0.04
Radon (pCi/L)	Subsurface	NM	NM	NM	142 +/- 16	0.23 +/- 0.15	0.1	134 +/- 38	0.1 +/- 0	0.1
Parris Island New Dry Cleaner Facility										
Benzene (ug/m^3)	Above ground	NM	NM	NM	2.0 +/- 1.2	0.43 +/- 0.023	0.46	0.75 +/- 0.27	***0.69 +/- 0.015***	0.84
Toluene (ug/m^3)	Above ground	NM	NM	NM	6.0 +/- 3.9	10 +/- 4.6	1.6	2.3 +/- 0.06	5.3 +/- 0.25	2.7
SF_6 (ug/m^3)	Above ground	NM	NM	NM	7.1 +/- 1.0	109 +/- 57	<10	<6.4 +/- 0	119 +/- 57	<9.1
PCE (ug/m^3)	Subsurface*	NM	NM	NM	153 +/- 56	21 +/- 8.9	0.29	108 +/- 46	***47 +/- 9.6***	0.43
Radon (pCi/L)	Subsurface	NM	NM	NM	2,498 +/- 190	0.26 +/- 0.046	0.11	2,337 +/- 230	0.38 +/- 0.12	0.22

Table 5.7.5: Chemical Concentrations in Demonstration Buildings (Continued)

		Baseline Pressure			Negative Pressure			Positive Pressure		
		Sub-slab	Indoor Air	Ambient Air	Sub-slab	Indoor Air	Ambient Air	Sub-slab	Indoor Air	Ambient Air
Building 102, Tinker AFB										
Benzene (ug/m^3)	Above ground	NM	NM	NM	10 +/- 16	0.66 +/- 0.15	0.66	4.2 +/- 4.6	0.40 +/- 0.008	0.56
Toluene (ug/m^3)	Above ground	NM	NM	NM	17 +/- 15	5.87 +/- 0.7	8.5	9.2 +/- 3.1	***0.59 +/- 0.064***	1.7
PCE (ug/m^3)	Subsurface	NM	NM	NM	43 +/- 33	4.7 +/- 2.8	5.9	***26 +/- 32***	0.34 +/- 0.063	1.2
Radon (pCi/L)	Subsurface	NM	NM	NM	86 +/- 82	0.25 +/- 0.072	0.21	37 +/- 57	0.18 +/- 0.026	0.27
ASU Research House, Hill AFB (Round 1)*										
Benzene (ug/m^3)	Above ground	0.25 +/- 0.12	0.48 +/- 0.07	0.50	0.94 +/- 0.63	0.45 +/- 0.01	0.39	0.21 +/- 0.12	0.55 +/- 0.07	0.54
Toluene (ug/m^3)	Above ground	3.15 +/- 3.97	2.20 +/- 0.40	1.50	2.04 +/- 1.72	***1.40 +/- 0.17***	0.87	0.81 +/- 0.46	***2.47 +/- 0.40***	2.20
SF_6 (ug/m^3)	Above ground	2,333 +/- 1,656	8,900 +/- 1,825	12	56.3 +/- 64.0	***1,113 +/- 1,115***	<9.8	1,227 +/- 748	1,595 +/- 1,419	<12
DCE (ug/m^3)	Subsurface	5.40 +/- 9.18	0.13 +/- 0.02	<0.04	169 +/- 132	6.10 +/- 5.24	<0.04	6.52 +/- 9.95	0.04 +/- 0.003	<0.05
TCE (ug/m^3)	Subsurface	11.4 +/- 8.86	6.80 +/- 0.44	0.21	220 +/- 182	9.80 +/- 7.30	0.12	6.90 +/- 4.42	0.33 +/- 0.22	0.13
Radon (pCi/L)	Subsurface	252+/- 364	0.39 +/- 0.06	0.48	261 +/- 313	2.44 +/- 1.49	0.18	211 +/- 337	0.03 +/- 0.06	0.09
ASU Research House, Hill AFB (Round 2)*										
Benzene (ug/m^3)	Above ground	0.39 +/- 0.03	0.46 +/- 0.02	0.39	***0.74 +/- 0.10***	0.46 +/- 0.02	0.42	0.45 +/- 0.11	***0.57 +/- 0.02***	0.57
Toluene (ug/m^3)	Above ground	2.70 +/- 0.98	4.08 +/- 2.41	3.90	5.42 +/- 5.70	3.07 +/- 1.19	1.90	2.53 +/- 1.01	2.27 +/- 0.45	1.8
SF_6 (ug/m^3)	Above ground	750 +/- 823	5200 +/- 1253	<8.8	53.3 +/- 57.9	***780 +/- 710***	12	990 +/- 615	867 +/- 810	11
DCE (ug/m^3)	Subsurface	4.78 +/- 7.13	0.12 +/- 0.01	<0.04	231 +/- 188	6.23 +/- 4.41	<0.04	7.54 +/- 10.8	<0.04 +/- 0.004	<0.04
TCE (ug/m^3)	Subsurface	10.3 +/- 3.52	18.8 +/- 3.33	0.17	268 +/- 225	9.47 +/- 6.07	0.15	9.60 +/- 3.03	0.15 +/- 0.04	0.06
Radon (pCi/L)	Subsurface	184 +/- 234	0.38 +/- 0.14	0.10	207 +/- 179	1.87 +/- 1.99	0.03	168 +/- 262	0.09 +/- 0.07	0.07

Table 5.7.5: Chemical Concentrations in Demonstration Buildings (Continued)

		Baseline Pressure			Negative Pressure			Positive Pressure		
		Sub-slab	Indoor Air	Ambient Air	Sub-slab	Indoor Air	Ambient Air	Sub-slab	Indoor Air	Ambient Air
Building 107, Moffett Field (Round 1)										
Benzene (ug/m^3)	Above ground	12.5 +/- 16.3	0.45 +/- 0.01	0.46	4.22 +/- 3.85	***<u>0.26 +/- 0.02</u>***	0.27	2.51 +/- 2.67	0.49 +/- 0.19	0.40
Toluene (ug/m^3)	Above ground	23.0 +/- 24.0	1.83 +/- 0.31	2.10	13.8 +/- 9.89	***<u>1.29 +/- 0.42</u>***	3.40	8.15 +/- 6.86	5.13 +/- 5.16	1.60
SF_6 (ug/m^3)	Above ground	39.7 +/- 48.0	1,600 +/- 200	<9.1	53.0 +/- 38.9	***<u>257 +/- 120</u>***	<9.1	234 +/- 183	387 +/- 49	<11
PCE (ug/m^3)	Subsurface	3.15 +/- 0.49	1.90 +/- 0.26	0.08	2.48 +/- 1.55	1.57 +/- 0.31	0.05	2.15 +/- 1.34	***<u>0.10 +/- 0.03</u>***	0.06
TCE (ug/m^3)	Subsurface	1.35 +/- 1.35	2.93 +/- 0.32	0.05	2.15 +/- 1.58	***<u>2.33 +/- 0.42</u>***	<0.04	1.55 +/- 0.92	***<u>0.09 +/- 0.04</u>***	0.05
Radon (pCi/L)	Subsurface	406 +/- 210	0.65 +/- 0.09	0.12	333 +/- 259	0.46 +/- 0.20	0.03	250 +/- 312	***<u>0.06 +/- 0.11</u>***	0.05
Building 107, Moffett Field (Round 2)										
Benzene (ug/m^3)	Above ground	1.37 +/- 1.19	1.12 +/- 0.03	1.10	1.06 +/- 0.83	***<u>1.57 +/- 0.12</u>***	1.50	1.03 +/- 0.41	1.53 +/- 0.06	1.4
Toluene (ug/m^3)	Above ground	4.20 +/- 2.69	4.00 +/- 0.30	3.50	3.72 +/- 1.91	9.57 +/- 4.92	9.40	4.10 +/- 0.66	8.50 +/- 0.10	10.0
SF_6 (ug/m^3)	Above ground	1,200 +/- 954	3,300 +/- 265	18	118 +/- 70.9	***<u>563 +/- 237</u>***	16	470 +/- 341	530 +/- 450	18
PCE (ug/m^3)	Subsurface	2.02 +/- 1.18	2.83 +/- 0.12	0.12	3.16 +/- 2.64	2.00 +/- 0.56	0.21	1.63 +/- 1.37	***<u>0.42 +/- 0.02</u>***	0.89
TCE (ug/m^3)	Subsurface	2.01 +/- 1.10	4.95 +/- 0.22	0.08	1.85 +/- 0.68	***<u>3.13 +/- 0.91</u>***	0.12	1.15 +/- 1.01	***<u>0.12 +/- 0.02</u>***	0.09
Radon (pCi/L)	Subsurface	297 +/- 279	1.00 +/- 0.05	0.18	374 +/- 226	0.62 +/- 0.16	0.26	357 +/- 342	0.30 +/- 0.10	0.33

Note: Results shown are the average +/- standard deviation from 3 sub-slab and indoor air locations. Detection limit substituted for non-detect results. Duplicates averaged. Hill and Moffett Round 1 radon results are from the RAD7 portable radon detector. All other results are from laboratory analysis. ***<u>Bold, underlined, italic</u>*** = statistically significant change compared to prior pressure condition based on paired t-test (See Table 6.3.1).

* = Indoor air concentration does not include additional sampling and analysis conducted at indoor air sample location IA-2 using the portable HAPSITE GC/MS. Analytical results for this supplemental sampling are provided in Appendix A.6.

5.7.2.3 Cross-Foundation Pressure Gradients: For each demonstration building, foundation permeability was evaluated by comparing the cross-foundation pressure gradient to the pressure gradient across the building envelope (Table 5.7.6). In order to support an evaluation of the correlation between foundation permeability and vapor intrusion, the foundation permeability for each building was classified as high, medium, or low as described in the Table 5.7.6 footnotes.

Table 5.7.6: Average Pressure Gradients during Tier 3 Demonstrations

Site	Average Pressure Gradient (Pa)[1]		Foundation Permeability Classification[2]
	Cross-Building Envelope	Cross-Foundation	
Travis AFB	NP: -2.9 PP: +2.4	NP: -0.15 (5%) PP: +0.002 (<1%)	High
Jacksonville NAS	NP: -0.15 PP: +1.9	NP: +0.05 (-33%) PP: -0.005 (<-1%)	High
Parris Island	NP: -3.9 PP: -2.0	NP: +0.10 (-3%) PP: +0.53 (-27%)	High
Tinker AFB	NP: -15.2 PP: +11.1	NP: -4.5 (30%) PP: +2.0 (18%)	Medium (Low)
Hill AFB (Round 1)	BL: NM NP: NM PP: NM	BL: +0.91 NP: -2.0 PP: +2.8	Low
Hill AFB (Round 2)	BL: +0.87 NP: -5.2 PP: +3.9	BL: +0.35 (40%) NP: -2.1 (41%) PP: +2.6 (66%)	
Moffett Field (Round 1)	BL: -0.49 NP: --2.3 PP: +1.1	BL: -0.19 (39%) NP: -1.5 (66%) PP: +0.45 (39%)	Low
Moffett Field (Round 2)	BL: -0.84 NP: -2.5 PP: +1.0	BL: -0.24 (29%) NP: -1.2 (50%) PP: +0.46 (45%)	

Note: 1) Average pressure gradient is average of readings automatically recorded every 5 to 15 minutes during period of induced pressure control. Negative value indicates that pressure inside building is lower than outside building. Detailed pressure measurement results are provided in Appendix A. BL = baseline pressure test condition, NP = negative pressure test condition, PP = Positive pressure test condition.
2) Foundation permeability classified based on comparison of cross-foundation gradient to cross-building envelope gradient. High = cross-foundation <10% cross-envelope, Medium = cross-foundation is 10-40% of cross-envelope, Low = cross-foundation >40% cross-envelope. For the "Medium" permeability sites, the secondary classification is Low = cross-foundation >40% cross-envelope.

5.7.2.4 Magnitude of Vapor Intrusion: The magnitude of vapor intrusion in each building was evaluated based on the sub-slab to indoor air attenuation factor corrected for the contribution of ambient (outdoor) sources:

$$AF_{SS-IA} = \frac{C_{IA} - C_{AA}}{C_{SS}}$$

Where:
AF_{SS-IA} = Sub-slab to indoor air attenuation factor (unitless)
C_{IA} = Average COC concentration in indoor air ($\mu g/m^3$)
C_{AA} = Average COC concentration in ambient air ($\mu g/m^3$)
C_{SS} = Average COC concentration in sub-slab ($\mu g/m^3$)

Attenuation factors were not calculated when the COC concentration in ambient air was higher than the COC concentration in indoor air. The results of the attenuation factor calculations are presented in Table 5.7.7. The statistical uncertainty associated with the attenuation factor was determined by combining the standard deviation associated with each average concentration value as follows:

Adding or Subtracting: When adding or subtracting means of measurements, the associated standard deviations are summed as follows:

$$\sigma_x = \sqrt{\sigma_y^2 + \sigma_z^2}$$

Multiplying or Dividing: When multiplying or dividing means of measurements, the standard deviations are combined as follows:

$$\sigma_x = x\sqrt{\frac{\sigma_y^2}{y^2} + \frac{\sigma_z^2}{z^2}}$$

A higher attenuation factor (i.e., closer to 1) indicates more vapor intrusion. In order to evaluate the correlation between foundation permeability and vapor intrusion, each building was assigned a preliminary classification as a high, medium, or low vapor intrusion building based on the observed attenuation factors. The radon attenuation factor under negative building pressure conditions was used to make the vapor intrusion classification because i) vapor intrusion was expected under negative pressure conditions, but not positive pressure conditions, and ii) the radon attenuation factor is not confounded by potential indoor sources. The building-specific vapor intrusion classifications are summarized in Table 5.7.7.

Table 5.7.7: Attenuation Factors Measured for Chemicals with Subsurface Sources

Chemical	Attenuation Factor		Magnitude of Vapor Intrusion*
	Negative Pressure	Positive Pressure	
Building 828, Travis AFB			
TCE	0.097 +/- 0.12	NA	Low
Radon	3.0×10^{-4} +/- 4.1×10^{-5}	NA	
Building 103, Jacksonville NAS			
PCE	7.7×10^{-5} +/- 3.8×10^{-5}	3.1×10^{-5} +/- 1.6×10^{-5}	Medium (High)
TCE	8.4×10^{-5} +/- 4.0×10^{-5}	7.1×10^{-5} +/- 2.9×10^{-5}	
Radon	9.3×10^{-4} +/- 6.2×10^{-4}	1.0×10^{-19} +/- 2.9×10^{-20}	
Parris Island New Dry Cleaner Facility			
PCE	0.15 +/- 0.094	0.43 +/- 0.20	Low
Radon	6.0×10^{-5} +/- 1.2×10^{-5}	6.8×10^{-5} +/- 2.3×10^{-5}	
Building 102, Tinker AFB			
PCE	NA	NA	Low
Radon	4.6×10^{-4} +/- 4.6×10^{-4}	NA	
ASU Research House, Hill AFB (Round 1)			
1,1-DCE	0.036 +/- 0.042	NA	High
TCE	0.044 +/- 0.049	0.029 +/- 0.027	
Radon	8.6×10^{-3} +/- 1.2×10^{-2}	NA	
ASU Research House, Hill AFB (Round 2)			
1,1-DCE	0.027 +/- 0.029	4.4×10^{-4} +/- 6.3×10^{-4}	High
TCE	0.047 +/- 0.070	8.6×10^{-3} +/- 3.4×10^{-3}	
Radon	8.4×10^{-3} +/- 1.1×10^{-2}	1.3×10^{-4} +/- 2.1×10^{-4}	
Building 107, Moffett Field (Round 1)			
TCE	1.1 +/- 0.81	0.025 +/- 0.019	Medium (High)
PCE	0.61 +/- 0.40	0.017 +/- 0.012	
Radon	1.2×10^{-3} +/- 1.1×10^{-3}	5.3×10^{-5} +/- 1.1×10^{-4}	
Building 107, Moffett Field (Round 2)			
TCE	4.6 +/- 3.4	1.1 +/- 1.2	Medium (High)
PCE	1.6 +/- 0.76	0.024 +/- 0.022	
Radon	9.9×10^{-4} +/- 7.1×10^{-4}	NA	

NA = Not applicable, concentration in ambient air greater than concentration in indoor air.
* = Magnitude of vapor intrusion based on the radon attenuation factor (AF) during the negative pressure condition. High = Radon AF > 5×10^{-3}, Medium = Radon AF between 5×10^{-3} and 5×10^{-4}, Low = Radon AF < 5×10^{-4}. For the "Medium" vapor intrusion sites, the secondary classification is High = Radon AF > 5×10^{-4}.

6.0 PERFORMANCE ASSESSMENT

A summary of all data analysis in support of the assessment of performance objectives is provided in this section.

6.1 COLLECTION OF DATA REPRESENTATIVE OF SITE CONDITIONS

The collection of site data that is representative of actual site conditions has been achieved by adhering to the sampling and analysis procedures specified in Section 5. Quality assurance/quality control (QA/QC) samples have been collected to allow for the evaluation of data precision, accuracy, completeness, representativeness, and comparability.

6.1.1 Data Quality Review

As specified in the demonstration plan, we have reviewed the analytical results for groundwater, soil gas, sub-slab vapor, indoor air, and ambient air samples, as well as soil geotechnical samples, to evaluate data usability. The data were screened based on i) sampling procedures, ii) custody procedures, iii) precision assessment, iv) accuracy assessment, v) soil properties, and vi) completeness.

6.1.1.1 Sampling Procedures: Groundwater, vapor and soil samples submitted for laboratory analysis were collected in accordance with Standard Operating Procedures (SOPs) routinely utilized by GSI or sample collection methods validated during previous field programs, as detailed in the Quality Assurance Project Plan (Appendix D of the Demonstration Plan). During the field programs covered by this report, the following deviations from planned procedures occurred:

- Soil gas samples from sampling points screened in low permeability soils were collected into Tedlar bags instead of Summa canisters because this sampling procedure allowed collection of smaller sample volumes.
- At the Former Pioneer Cleaners site, soil gas samples were not analyzed for SF_6 (the leak tracer) due to an instrument failure at the laboratory selected for analysis of these samples (SPL, Houston, Texas).
- At Tinker AFB, the indoor air tracer gas (SF_6) was not used because the gas cylinder was ordered from the supplier but the correct cylinder could not be obtained in time for the demonstration.
- At Parris Island Marine Base, a Tier 2 evaluation was planned but not completed because groundwater was observed at less than 5 ft bgs.
- At Moffett Field, volatile organic carbons by USEPA Method TO-15 could not be analyzed from the Subslab-1 sample from baseline conditions on 10/29/2010 because of a Summa canister valve malfunction. TO-15 analysis also could not be conducted on the Subslab-2 sample from the positive pressure condition on 10/31/2010 because of debris in the threads of the canister valve.
- The Tier 3 evaluation was conducted twice in a row at Hill AFB (ASU House) and at Moffett Field. Sub-slab radon was measured with a RAD7 portable radon detector (Durridge Company, Billercia, MA) during both rounds of sampling at each site. Sub-

slab samples were collected in Tedlar bags for radon laboratory analysis only during the second round of sampling. Indoor and ambient air samples were collected in Tedlar bags for radon analysis during both rounds of sampling at each site.

- Helium (rather than SF_6) was used as the leak check compound for the Tier 2 demonstrations at the Hill AFB, SPAWAR OTC, NIKE, and Southeast Texas Industrial sites. Helium and SF_6 are equally good leak check compounds.

Evaluation of Leakage during Collection of Soil Gas Samples: At the Tier 2 demonstration sites, entrainment of atmospheric air during the collection of soil gas samples was evaluated using SF_6 or helium as a leak tracer. The sample train is illustrated in Figure 5.6.1. SF_6 was used at the Former Pioneer Cleaners, Travis AFB, and Tinker AFB sites. As noted above, the soil gas samples from the Former Pioneer Cleaners site were not analyzed for SF_6 due to a laboratory instrument failure. Helium was used as the leak check compound at the Hill AFB, SPAWAR OTC, NIKE and Southeast Texas Industrial sites. The majority of soil gas samples had no detectable leak tracer compound. For the samples with detectable leak tracer compound, none of the leakage rates was greater than 10%, the standard threshold for unacceptable leakage. Only one sample, from Tinker AFB, showed a leakage rate of greater than 1%. Based on these results, no soil gas samples were affected by unacceptable leakage.

6.1.1.2 Custody Procedures, Holding Time, and Arrival Temperatures: All samples submitted for analysis were received within the required holding times and within the limits specified for temperature for groundwater samples except for groundwater samples collected at the NIKE site. Due to a shipping error within FedEx®, groundwater samples from the NIKE site were delivered to the incorrect analytical laboratory and arrived with all ice melted. The samples were repackaged with a new ice pack, and shipped overnight to the correct analytical laboratory. Therefore, the samples were not kept within acceptable sample receipt temperatures (between 2.0-6.0º C) during shipment.

All samples were submitted under chain-of-custody control with no indication of any losses of custody. Chain of custody documentation was provided by the final recipient of the samples to document the complete series of custody transactions.

Groundwater samples were analyzed by SPL, Inc. (Former Pioneer Cleaners samples), Calscience Environmental Laboratories, Inc. (Travis AFB samples), Test America Laboratories, Inc. (Tinker AFB, NIKE, Hill AFB, and Southeast Texas Industrial Site samples), and H&P Mobile Geochemistry Inc. (SPAWAR OTC samples) according to applicable standard operating procedures, laboratory guidelines, and in accordance with the chain-of-custody. One discrepancy in the number of blank samples received by the laboratory for the Travis AFB groundwater sampling event was noted on the corresponding chain-of-custody.

Vapor samples from the Travis AFB, Tinker AFB, Jacksonville NAS, Parris Island Marine Base, Hill AFB, Moffett NAS, NIKE and Southeast Texas Industrial sites were analyzed by Columbia Analytical Services. Soil gas samples from the Pioneer Cleaners site were analyzed by SPL, Inc. Soil gas samples from SPAWAR OTC were analyzed by H&P Mobile Geochemistry Inc. Radon samples for all sites, where collected for laboratory analysis, were analyzed by the University of

Southern California. Sample handling was conducted according to the laboratories' quality assurance programs and the chain-of-custody.

Soil properties analyses were conducted by Fugro Consultants, Inc. All but one soil sample from the Pioneer, Travis, Tinker, Hill AFB, NIKE and Southeast Texas Industrial sites were received in conditions suitable for analysis (i.e., undisturbed soil core samples). Intrinsic permeability and native hydraulic conductivity could not be measured in samples from the SPAWAR OTC site because the samples were fractured upon delivery or were too non-cohesive for analysis. Therefore, the geotechnical laboratory analyzed for dry bulk density and volumetric content using ASTM Method D 2166.

6.1.1.3 Precision Assessment: Duplicate Samples, Matrix Spike (MS), Matrix Spike Duplicate (MSD), Laboratory Control Sample (LCS), and Laboratory Control Sample Duplicate (LCSD): The precision assessment evaluates the agreement in analytical results between duplicate samples (field duplicates and laboratory duplicates). Precision was evaluated in accordance with the QAPP by calculating the relative percent difference (RPD) between duplicate samples.

Field Precision: A total of 37 field duplicate samples were collected from the sites covered by this report: 9 duplicate groundwater samples, and 28 duplicate gas samples (i.e., soil gas, sub-slab, indoor air, ambient air). The precision objective for the field samples is an RPD ≤ 30%. RPD values for duplicate samples were calculated for 7 key VOCs (1,1-DCE, benzene, toluene, cis-1,2-DCE, PCE, TCE, and VC) plus SF_6 and radon. RPDs were only calculated when these compounds were detected in at least one of the two duplicate samples analyzed. In the case that either the sample or the duplicate result was reported as non-detect, and the second sample resulted in a reported detection, the RPD was calculated based on the difference between the reported detection limit for the non-detect sample and the detected result for the other sample. For example, sub-slab vapor concentration for SF_6 at the Parris Island Recruit Depot was reported as not detected (ND) (<6.6 $\mu g/m^3$), with the duplicate reported as a detection of 10.0 $\mu g/m^3$. The RPD value for this COC was calculated based on sub-slab SF_6 concentrations of 6.6 $\mu g/m^3$ and 10.0 $\mu g/m^3$. Results of the field duplicate analysis are presented in Appendix E and are summarized in Table 6.1.1 below.

Table 6.1.1: Summary of Field Duplicate Precision

Matrix	Total RPD Calculations	Relative Percent Difference		
		≤30%	30 – 67%	>67%
Groundwater	23	22	0	1
Soil Gas	27	16	6	5
Sub-Slab Gas	43	35	6	2
Indoor Air	47	39	7	1
Ambient Air	10	2	8	0

Overall, 150 RPD values were calculated for the available field data, with 76% (114 of 150) meeting the RPD criteria of ≤ 30%. Eighteen percent (27 of 150) results that exceeded the RPD criteria had an RPD of less than 67% (2-fold difference). Six percent (9 of 150 samples) had an RPD of greater than 67%.

Laboratory Precision: Laboratory precision of groundwater samples is demonstrated by RPD values calculated for the MS/MSD and LCS/LCSD samples. Quality control analysis of groundwater samples conducted by the laboratories listed above for the identified key COCs resulted in all RPD values meeting the RDP criteria of ≤25%. Similarly, laboratory precision of the TO-15 and TO-15 SIM methods is demonstrated by RPD values of laboratory analyzed duplicate samples which are not field collected. The RPD results reported by the laboratories for the identified key COCs all meet the criteria of RPD ≤25% for the gas analysis methods. Complete laboratory reports for all analyses are provided in Appendix D.

6.1.1.4 Accuracy Assessment: The objectives for field accuracy and laboratory accuracy were defined in Section 3.2 of the QAPP. The results of the data evaluation based on these objectives are provided below.

Field Accuracy: The evaluation of field accuracy was based on the analytical results obtained for groundwater trip blanks and field blank samples. As defined in the QAPP, field accuracy will be met if analyte concentrations in the trip blank and field blank samples are below project quantitation limits. As shown in Appendix E, the field blanks and trip blanks from the Pioneer Cleaners, Travis AFB and Tinker AFB sites, as well as the trip blanks from the Hill AFB, SPAWAR OTC, NIKE, and Southeast Texas Industrial sites successfully met the accuracy criteria. The field blank collected at the Tinker AFB site met the accuracy criteria for the identified key COCs except for the detection of TCE in one blank sample (0.0006 mg/L). Based on this detection, field samples associated with this blanks were qualified as non-detect if the reported concentration of TCE was less than 0.003 mg/L, five times the concentration in the blank sample.

Laboratory Accuracy*:* Laboratory accuracy was assessed based on percent recoveries from MS/MSD, LCS/LCSD, and surrogate samples. For the key analytes, all samples analyzed by Methods TO-15 and TO-15 SIM were acceptable based on the results provided by the laboratories. Although percent recovery control criteria deviations were noted from a few chemicals, none of the chemicals were key compounds and, therefore, the exceedances did not affect interpretation of the results.

All the accuracy values derived from the MS/MSD, LCS/LCSD, and surrogate recoveries from the groundwater samples collected at the Former Pioneer Cleaners, Travis AFB, Hill AFB, SPAWAR OTC, and NIKE sites (reported as percent recoveries) successfully met the proposed accuracy criteria for the identified key compounds. Laboratory quality control analysis conducted for groundwater samples from the Tinker AFB Site resulted in exceedances of the accuracy criteria for TCE and VC, two of the identified key compounds. The reported bias for both the compounds was high, with percent recoveries ranging from 143% to 157% for TCE (accuracy criteria limits: 56%-118%), and 144% for the vinyl chloride MSD sample (accuracy criteria limits: 60%-140%). Based on these reported recoveries, the associated results for TCE and VC for the samples collected at the Tinker AFB Site may be biased high. These samples were qualified with an "H" to reflect this potential high bias, however, the magnitude of the potential high bias (approximately 50%) is not enough to affect the interpretation of the results. At the Southeast Texas Industrial site, the laboratory reported low 1,1-DCE and cis-1,2-DCE recovery in the MS sample because of matrix interference. Recovery for these compounds was within range for the MSD, and the MS/MSD RPD met the RPD criteria.

<u>6.1.1.5 Soil Properties:</u> All soil property analyses were conducted by an accredited laboratory according to laboratory SOPs, and analytical methods and quality control checks as stipulated by API and ASTM. Soil properties of undisturbed samples, including intrinsic permeability, porosity, bulk density, volumetric water content, and fraction organic carbon were analyzed. Samples were analyzed for the above-referenced properties, except for the following. At Tinker AFB, the sample from C1-PZ-2, 9.0 to 10 ft interval could not be analyzed for the above mentioned properties due to sample fracturing and breakage during transport. No samples from SPAWAR OTC could be analyzed for intrinsic permeability and native hydraulic conductivity because the samples were fractured upon delivery to the laboratory or were too non-cohesive. The available soil characteristics data was deemed usable for the purpose of this investigation.

<u>6.1.1.6 Completeness Assessment:</u> With the exceptions noted in Section 6.1.1.1 (Sampling Procedures), all necessary analytical samples were collected and analyzed.

6.1.2 Evaluation of Data Quality Performance Objective

The data quality exceptions noted in the data quality review are typical of environmental field programs and none of these exceptions limit the usability of the results obtained. The results of the data quality review are summarized in Table 6.1.2.

Table 6.1.2: Summary of Data Evaluation Results

Data Quality Objective	Results of Data Quality Evaluation			
	Groundwater	TO-15 SIM	TO-15	Radon
Sampling Procedures	Acceptable	Acceptable	Acceptable*	Acceptable
Custody Procedures	Acceptable*	Acceptable	Acceptable	Acceptable
Holding Time	Acceptable	Acceptable	Acceptable	Acceptable
Temperature on Arrival	Acceptable	NA	NA	NA
Field Duplicate Samples	Acceptable*	Acceptable*	Acceptable*	Acceptable
MS/MSD Samples	Acceptable*	NA	NA	NA
LCS/LCSD Samples	Acceptable	Acceptable*	Acceptable	NA
Blank Analysis	Acceptable*	Acceptable	Acceptable*	NA
Completeness Assessment	Acceptable	Acceptable	Acceptable	Acceptable
Overall Data Usability	**Acceptable**	**Acceptable**	**Acceptable**	**Acceptable**

Acceptable = This Data Quality Objective (DQO) was evaluated and found to have met the requirements outlined in the QAPP. Acceptable* = This DQO was found to have deficiencies or exceptions as discussed in the text however, the data was determined to be usable. NA = DQO is not applicable to the indicated method

<u>Finding</u>: *The data quality for the demonstration program data set is acceptable and suitable for evaluation of the demonstration performance.*

6.2 VALIDATION OF TIER 2 SCREENING CRITERIA AND PROCEDURES

The hypothesis for validation of the Tier 2 screening criteria is that VOC attenuation in the vadose zone is higher at sites with high moisture content fine-grained soil layers on top of the shallowest water-bearing unit (i.e., a confining layer) or within the vadose zone.

6.2.1 Attenuation Factor Calculations

The hypothesis for the Tier 2 demonstration is that vadose zone or groundwater to deep soil gas attenuation factors are higher at sites with high moisture content fine-grained soils compared to sites without this characteristic. To evaluate this hypothesis, attenuation factors have been calculated as follows:

$$AF_{GW-DSG} = \frac{C_{DSG}}{C_{GW} \times H'}$$

Where:

$AF_{GW\text{-}DSG}$	=	Groundwater to deep soil gas air attenuation factor (unitless)
C_{DSG}	=	VOC concentration in deepest soil gas point sampled (µg/m^3)
C_{GW}	=	VOC concentration groundwater (average of all measurements from cluster, µg/m^3)
H'	=	Henry's Law constant (unitless)

For each site, the data analysis was focused on the three VOCs detected most consistently in groundwater at the three sample point clusters. At Travis AFB, only two VOCs (TCE and cis-1,2-DCE) were detected at more than one sample cluster (see Appendix A.2). As a result, only these two VOCs were included in the attenuation factor analysis. For VOC concentrations in groundwater, the average VOC concentrations from the vertically-spaced monitoring points within a single cluster was used as the concentration most representative of that measured using a typical shallow groundwater monitoring well.

<u>Pioneer Cleaners, Confined Aquifer Site</u>: The Pioneer Cleaners site showed clear confined aquifer conditions with an 8 to 12 ft clay confining layer above the shallowest water-bearing unit and the potentiometric surface observed 16 to 18 ft above the shallowest groundwater-bearing unit. At this site, the deepest groundwater monitoring point at each cluster was completed at the top of the groundwater-bearing unit, three additional groundwater monitoring points were spaced between the groundwater-bearing unit and the potentiometric surface, and one groundwater monitoring point was installed above the potentiometric surface. The five soil gas monitoring points were spaced between the expected elevation of the potentiometric surface and ground surface (see Appendix A.1).

All soils above the groundwater-bearing unit were classified as clays, silty-clays, or clayey-silts. Laboratory and field testing confirmed the low permeability of the soils with native hydraulic conductivity (lab test) ranging from 6.9 x 10^{-10} cm/sec to 9.4 x 10^{-8} cm/sec except for one sample with a conductivity of 2.8 x 10^{-6} cm/sec (see Appendix A.1). High moisture content (average = 90%, range = 78% to 99% by volume) was observed in all soil samples. Field permeability testing conducted at dry groundwater monitoring points showed very low soil permeability (8.4 x 10^{-11} to 3.1 x 10^{-10} cm^2, Appendix A.1) consistent with high moisture content clay soils. In addition, high vacuum was observed during collection of most of the soil gas samples, further confirming the low permeability of the soils.

PCE, TCE, and cis-1,2-DCE were detected at elevated concentrations within the shallow groundwater-bearing unit at two of the three cluster locations (e.g., 16 mg/L PCE at Cluster 1 and 0.1 mg/L PCE at Cluster 3). However, with the exception of one trace detection of PCE (0.006 mg/L at Cluster 1 PZ-3), these VOCs were not detected in any groundwater samples collected from the confining layer or any soil gas samples. These results indicate that the confining layer at the Pioneer Cleaners site serves as an effective barrier to vapor intrusion. A graph of the vertical profile of VOCs at each sample point cluster is provided in Appendix A.1. Although the absence of VOCs in soil gas prevents the calculation of an accurate groundwater to deep soil gas attenuation factor, this attenuation factor is less than 8.5×10^{-6} (see Table 6.2.1) based on the detected concentration of PCE in the groundwater-bearing unit at Cluster 1 (16 mg/L; equivalent to soil vapor concentration of 1.2×10^{7} µg/m^3 assuming equilibrium partitioning) and the approximate detection limit for PCE in the deepest soil gas sample (100 µg/m^3).

Table 6.2.1: Groundwater to Deep Soil Gas Attenuation Factors, Former Pioneer Cleaners Site

Sample Point Cluster	VOC		
	PCE	TCE	cis-1,2-DCE
1	$<8.5 \times 10^{-6}$	$<2.0 \times 10^{-4}$	$<3.2 \times 10^{-4}$
2	N/A	N/A	N/A
3	$<2.2 \times 10^{-3}$	$<8.9 \times 10^{-3}$	$<2.6 \times 10^{-3}$

N/A = Not applicable, VOC not detected in groundwater.

<u>Travis AFB, Fine-grained Soils at Water Table</u>: Groundwater conditions at Travis AFB were not clearly confined or unconfined. At the water table, soil type at the three clusters ranged from silty clay to clayey sand. The soils above and below the water table were characterized by interbedded layers of silty sands, silts, and clays. The deepest groundwater monitoring point at each cluster was installed in a thin silty sand layer located about 5 ft below the water table. The remaining groundwater monitoring points were spaced below and above the water table to support characterization of vertical concentration profiles. The soil gas sampling points were spaced between the water table and ground surface (see Appendix A.2).

Laboratory testing indicated low permeability of the soils with native hydraulic conductivity (lab test) ranging from 1.8×10^{-9} cm/sec to 4.6×10^{-7} cm/sec (Appendix A.2). High moisture content (average = 83%, range = 67% to 97% by volume) was observed in all soil samples. However, field permeability testing conducted at dry groundwater monitoring points showed higher soil permeability (4.6×10^{-9} to 2.4×10^{-8} cm^2, Appendix A.2) compared to the other fine-grained soil site, (i.e., about 100x higher soil permeability compared to the Pioneer Cleaners site).

Both TCE and cis-1,2-DCE were detected within the shallow groundwater at two of the three cluster locations (Clusters 2 and 3) and low concentrations of TCE were detected at Cluster 1. At all three clusters, a relatively modest vertical concentration gradient was observed within the groundwater with TCE concentrations decreasing by 30% to 70% between the deepest and shallowest monitoring points (a distance of 2 to 4 ft). At all three clusters, TCE was detected in the deepest soil gas sampling point (9 to 11.5 ft bgs, depending on the cluster) and concentrations decreased at shallower depths reaching non-detect concentrations (< 5 µg/m^3) at depths of 3.5 to 8.5 ft bgs. A graph of the vertical profile of VOCs at each sample point cluster is provided in Appendix A.2. Attenuation factors are provided in Table 6.2.2.

Table 6.2.2: Groundwater to Deep Soil Gas Attenuation Factors, Travis AFB Site

Sample Point Cluster	VOC	
	TCE	cis-1,2-DCE
1	2.9×10^{-2}	N/A
2	9.9×10^{-3}	2.2×10^{-2}
3	1.2×10^{-2}	1.0×10^{-3}

N/A = Not applicable, VOC not detected in groundwater.

Tinker AFB, Fine-grained Soils at Water Table: Groundwater conditions at Tinker AFB appeared to be unconfined based on the similar groundwater elevations observed in the vertically-spaced monitoring points installed at each cluster (see Appendix A.5). The shallowest water-bearing unit is a silty sand layer first encountered at a depth of 10 to 12 ft bgs. The soils above the unit were characterized by clayey silt and silty clay. The deepest groundwater monitoring point at each cluster was installed in the silty sand layer located about 3-5 ft below the water table. The remaining groundwater monitoring points were spaced below and above the water table to support characterization of vertical concentration profiles. The soil gas sampling points were spaced between the water table and ground surface (see Appendix A.5).

Laboratory and field testing confirmed the low permeability of the soils with native hydraulic conductivity (lab test) ranging from 1.6×10^{-9} cm/sec to 5.7×10^{-9} cm except for one soil core sample with a conductivity of 5.4×10^{-7} (Appendix A.5). High moisture content (average = 96%, range = 88% to 100% by volume) was observed in all soil samples. Field permeability testing conducted at dry groundwater monitoring points showed very low soil permeability (9.5×10^{-12} to 1.1×10^{-10} cm^2, Appendix A.5) consistent with high moisture fine-grained soils. The soil permeability was similar to the Pioneer Cleaners site and lower than the Travis AFB site. In addition, high vacuum was observed during collection of many of the soil gas samples, further confirming the low permeability of the soils.

TCE, cis-1,2-DCE, and VC were detected within the shallow groundwater at all three of the cluster locations, although only low concentrations were detected at Cluster 1 (i.e., < 5 µg/L). At Clusters 2 and 3, a relatively high vertical concentration gradient was observed within the groundwater with VOC concentrations decreasing about 90% between the deepest and shallowest monitoring points (a distance of 2 to 4 ft). TCE was not detected in any soil gas samples while VC was detected in the deepest soil gas sample at Cluster 3 and cis-1,2-DCE was detected in the two deepest soil gas samples from this cluster. A graph of the vertical profile of VOCs at each sample point cluster is provided in Appendix A.5. Attenuation factors are provided in Table 6.2.3.

Table 6.2.3: Groundwater to Deep Soil Gas Attenuation Factors, Tinker AFB Site

Sample Point Cluster	VOC		
	TCE	cis-1,2-DCE	VC
1	N/A	N/A	N/A
2	$<2.9 \times 10^{-5}$	$<8.9 \times 10^{-5}$	$<2.5 \times 10^{-5}$
3	$<3.3 \times 10^{-3}$	2.2×10^{-2}	2.6×10^{-4}

N/A = Not applicable, VOC not detected in most groundwater samples.

SPAWAR OTC Facility, Fine-grained Soils at Water Table: Groundwater conditions at the SPAWAR OTC Facility appeared to be unconfined based on the similar groundwater elevations observed in the vertically-spaced monitoring points installed at each cluster (see Appendix A.8). The shallowest water-bearing unit is a silty sand layer first encountered at a depth of 10 to 12 ft bgs grading to sand at 12 to 13 ft bgs. A one to two foot thick silty clay or clayey silt layer was present immediately above the top of the water-bearing zone (see Figure A.8.2). The deepest groundwater monitoring point at each cluster was installed in the sand/silty sand layer at a depth of about 13.5 ft bgs. The remaining groundwater monitoring points were spaced below and above the water table to support characterization of vertical concentration profiles. The soil gas sampling points were spaced between the water table and ground surface (see Appendix A.8).

Moisture content in soil samples ranged from 43% to 97% with an average of 77%. Moisture content was greater than 95% in the soil samples collected from the clay layer immediately above the water table at each of the three cluster locations. Laboratory permeability testing could not be completed because the soil cores were non-cohesive. However, field permeability testing confirmed the low permeability of the soils with soil permeability (5.3×10^{-11} to 3.3×10^{-8} cm^2, Appendix A.8). In addition, high vacuum was observed during collection of many of the soil gas samples, further confirming the low permeability of the soils.

VC, trans-1,2-DCE, and cis-1,2-DCE were detected within the shallow groundwater at two of the three cluster locations (i.e., Cluster 1 and Cluster 2). No VOCs were detected in groundwater at Cluster 3. With the exception of C2-SG-2, cis-1,2-DCE and trans-1,2-DCE were not detected in any of the soil gas samples and VC was detected at only low concentrations (11 $\mu g/m^3$ or less). Higher concentrations of cis-1,2-DCE, trans-1,2-DCE, and VC were detected at C2-SG-2. However, this sample point was completed within the clay layer above the water table and less than 1 ft above the potentiometric surface measured in the adjacent groundwater sample points. The high vacuum required to collect a sample from this point may have resulted in stripping of VOCs from the underlying groundwater. This hypothesis is supported by the groundwater to deep soil gas attenuation factors calculated for this point which ranged from 0.10 to 1.1, suggesting near equilibrium between this soil gas sample and the underlying groundwater. Based on this evaluation, the soil gas concentrations from the next shallower sample point (C2-SG-3) were used for the overall attenuation factor analysis. Attenuation factors for the SPAWAR OTC facility are provided in Table 6.2.4.

Table 6.2.4: Groundwater to Deep Soil Gas Attenuation Factors, SPAWAR OTC Site

Sample Point Cluster	VOC		
	cis-1,2-DCE	trans-1,2-DCE	VC
1	$<9.2 \times 10^{-3}$	$<1.1 \times 10^{-2}$	1.5×10^{-5}
2	$1.1/<4.7 \times 10^{-3}$ (1)	$0.45/<2.8 \times 10^{-3}$ (1)	$0.10/1.4 \times 10^{-5}$ (1)
3	N/A	N/A	N/A

N/A = Not applicable, VOC not detected in most groundwater samples.

1) For Cluster 2, attenuation factors are shown based on VOC concentrations measured in SG-2 and SG-3. The attenuation factors based on SG-3 (i.e., the lower values) are considered more representative because the SG-2 may have been screened near the bottom of the capillary fringe (see main text).

NIKE PR-58 Facility, Rhode Island, Medium-Grained Sandy Soils at Water Table: Groundwater conditions at the NIKE PR-58 facility were unconfined. The soils above and below the water table were predominately sandy with some silty sand near the ground surface. The deepest groundwater monitoring point at each cluster was installed in sandy soil at about 15 ft bgs and about 5 ft below the water table. The remaining groundwater monitoring points were spaced below and above the water table to support characterization of vertical concentration profiles. The soil gas sampling points were spaced between the water table and ground surface (see Appendix A.9).

Laboratory testing confirmed the higher permeability of the soils with native hydraulic conductivity (lab test) ranging from 4.9 x 10^{-3} cm/sec to 3.9 x 10^{-5} cm/sec (Appendix A.9). Moisture content (average = 67%, range = 25% to 95% by volume) was low compared to other sites with the highest moisture content values observed in close proximity to the water table. Field permeability testing conducted at dry groundwater monitoring points also showed higher soil permeability compared to the fine-grained soil site. The geometric mean of the soil permeability was 1.4 x 10^{-8} cm^2 and all values were >10^{-8} cm^2 except for only location (8.0 x 10^{-10} cm^2 at C1-PZ-4, Appendix A.9).

TCE and cis-1,2-DCE were detected within the shallow groundwater at all three cluster locations and PCE was detected at two clusters (Clusters 1 and 3). TCE was detected in soil gas at all three clusters. PCE was detected at Clusters 1 and 2, and cis-1,2-DCE was detected in soil gas at Cluster 1 (Appendix A.9). Attenuation factors for NIKE PR-58 are provided in Table 6.2.5.

Table 6.2.5: Groundwater to Deep Soil Gas Attenuation Factors, NIKE PR-58 Site

Sample Point Cluster	VOC		
	PCE	TCE	cis-1,2-DCE
1	4.2 x 10^{-2}	2.1 x 10^{-2}	5.6 x 10^{-3}
2	N/A	1.0 x 10^{-3}	<1.9 x 10^{-2}
3	<8.5 x 10^{-4}	2.8 x 10^{-4}	<9.6 x 10^{-4}

N/A = Not applicable, VOC not detected in most groundwater samples.

Hill AFB, Utah, Fine to Medium Grained Soils at Water Table: Groundwater conditions at the Hill AFB facility were unconfined. The soils above and below the water table were predominately sand and silty sand with approximately three feet of clayey silt at the ground surface and occasional layers of clayey silt below the water table. The deepest groundwater monitoring point at each cluster was installed in sand or silty sand at about 16 ft bgs and about 5 ft below the water table. The remaining groundwater monitoring points were spaced below and above the water table to support characterization of vertical concentration profiles. The soil gas sampling points were spaced between the water table and ground surface (see Appendix A.9).

Laboratory testing indicated relative high soil permeability compared to the finer-grained soil sites with native hydraulic conductivity (lab test) ranging from 7.0 x 10^{-4} cm/sec to 6.7 x 10^{-7} cm/sec (Appendix A.6). Moisture content (average = 79%, range = 33% to 99% by volume) was lower than the finer-grained soil sites although the moisture content was 95% or greater in all samples collected more than 7 ft bgs. Field permeability testing conducted at dry groundwater monitoring points also showed higher soil permeability compared to the fine-grained soil site. The geometric mean of the soil permeability was 1.7 x 10^{-8} cm^2 and all values were >10^{-8} cm^2 except for only location (1.3 x 10^{-9} cm^2 at C1-PZ-4, Appendix A.6).

TCE was detected within the shallow groundwater at all three cluster locations and cis-1,2-DCE and 1,1-DCE were detected at one cluster (Cluster 3). TCE was detected in soil gas at all three clusters while cis-1,2-DCE and 1,1-DCE were not detected in any of the soil gas samples (Appendix A.6). Attenuation factors for Hill AFB are provided in Table 6.2.6.

Table 6.2.6: Groundwater to Deep Soil Gas Attenuation Factors, Hill AFB

Sample Point Cluster	VOC		
	TCE	cis-1,2-DCE	1,1-DCE
1	0.025	N/A	N/A
2	0.052	N/A	N/A
3	0.017	<0.0083	<0.0015

N/A = Not applicable, VOC not detected in most groundwater samples.

Industrial Site, Southeast Texas, Fine to Medium-grained Soils at Water Table: Groundwater conditions at the Industrial Site were unconfined. Clayey silt soils were predominate in the first 10 ft bgs and the soils were predominately silty sand from 10 ft bgs to the bottom of the borings (25 ft bgs). The deepest groundwater monitoring point at each cluster was installed in silty sand at about 20 ft bgs and about 5 ft below the water table. The remaining groundwater monitoring points were spaced below and above the water table to support characterization of vertical concentration profiles. The soil gas sampling points were spaced between the water table and ground surface (see Appendix A.10).

Laboratory testing indicated relatively high soil permeability compared to the finer-grained soil sites with native hydraulic conductivity (lab test) ranging from 2.9 x 10^{-8} cm/sec to 2.6 x 10^{-4} cm/sec (Appendix A.10). Moisture content (average = 72%, range = 43% to 100% by volume) was lower than some of the finer-grained soil sites although the moisture content was 95% or greater in 4 of 5 samples collected from greater than 10 ft bgs. Field permeability testing conducted at dry groundwater monitoring points also showed higher soil permeability compared to the fine-grained soil site. The geometric mean of the soil permeability was 1.0 x 10^{-8} cm^2 with a range of 1.9 x 10^{-9} to 2.6 x 10^{-8} cm^2 (Appendix A.10).

PCE, 1,1-DCE, and cis-1,2-DCE were detected in groundwater and soil gas soil gas at all three clusters (Appendix A.10). Attenuation factors for the Industrial Site are provided in Table 6.2.7.

Table 6.2.7: Groundwater to Deep Soil Gas Attenuation Factors, Industrial Site, SE Texas

Sample Point Cluster	VOC		
	PCE	1,1-DCE	cis-1,2-DCE
1	0.073	0.026	0.032
2	0.20	0.10	0.28
3	0.61	0.38	0.49

6.2.2 Spatial Consistency in VOC Attenuation at Each Site

Within each site, good consistency was observed in groundwater to deep soil gas attenuation both between individual VOCs and between soil gas clusters. When a VOC was detected in both groundwater and soil gas, the attenuation factor was calculated based on the detected concentrations. When a VOC was detected in groundwater, but not soil gas, an upper-bound attenuation factor was calculated using the detected concentration in groundwater and the soil gas detection limit. When evaluating the actual attenuation factors (rather than the upper-bound attenuation factors), the variation between attenuation factors for a single site ranged from 1.1x to 150x. This range was much smaller than the 18,000x range of geometric mean attenuation factors between sites (i.e., 0.15 at the Industrial Site to $<8.5 \times 10^{-6}$ at the Former Pioneer Cleaners).

At Tinker AFB, the attenuation factor for cis-1,2-DCE at cluster 3 (2.2×10^{-2}) was much larger than the upper-bound attenuation factor for cis-1,2-DCE at cluster 2 ($<8.9 \times 10^{-5}$). A similar, but smaller, discrepancy was observed for vinyl chloride (i.e., 2.6×10^{-4} at cluster 3 vs. $<2.5 \times 10^{-5}$ at cluster 2). This difference in VOC attenuation between the two clusters corresponded to a measured difference in air permeability in the deep soils at the two clusters of 1.1×10^{-10} cm^2 at cluster 3 and 9.5×10^{-12} cm^2 at cluster 2 indicating a higher permeability at cluster 3.

At some locations, there was a large difference in attenuation for individual VOCs present at the same cluster location. For example, at Travis AFB Cluster 3, the attenuation factor for TCE was 1.2×10^{-2} while the attenuation factor for cis-1,2-DCE was 1.0×10^{-3}. Large differences were also observed at NIKE PR-58 Cluster 1 and Hill AFB Cluster 3. In all cases, the less chlorinated VOC showed higher attenuation than the more chlorinated VOC. This may indicate aerobic biodegradation of the less chlorinated VOC in the vadose zone. This would be consistent with observations noted in the literature (e.g., USGS, 2006) that less chlorinated VOCs more often biodegrade under aerobic conditions.

<u>Finding</u>: *The spatial consistency in VOC attenuation within each site supports the hypothesis that specific site characteristics can be used to predict VOC attenuation within the subsurface.*

6.2.3 Relationship between Site Characteristics and VOC Attenuation

In order to identify the relationship between measured site characteristics and VOC attenuation, a comparison of measured site characteristics and groundwater to deep soil gas attenuation factors was completed. As discussed in Section 3.2, the hypothesis for the Tier 2 evaluation method was that higher attenuation would be observed at sites with high moisture content fine-grained soils in the vadose zone directly above the water table. Moisture content was evaluated based on the testing of soil cores. The presence of fine-grained soils was evaluated using three methods:

<u>Soil Type at Water Table (Visual Field Determination)</u>: Soil type was determined in accordance with the USCS soil classification system based on visual inspection of the soil cores. For each site, conceptual cross sections are provided in Appendix A.

<u>Native Hydraulic Conductivity (Laboratory Measurement)</u>: Soil permeability was measured in the laboratory using soil cores. Results of geotechnical testing are provided in Appendix A.

Soil Permeability (Field Measurement): Soil permeability in the deep vadose zone was measured using a vacuum test (see Section 5.5.1). Results are provided in Appendix A.

The relationship between vadose zone soil characteristics and VOC attenuation from groundwater to deep soil gas is summarized in Table 6.2.8 (by individual cluster) and Table 6.2.9 (by site).

Table 6.2.8: Relationship between vadose zone soil characteristics and groundwater to deep soil gas attenuation factors: Location-based evaluation

Site	Cluster	Moisture Content (-)[2]	Soil Type at Water Table[1]	Native Hydraulic Conductivity (cm/sec)[1]	Field Soil Permeability (cm^2)[3]	Attenuation Factor (GW to Deep SG)[4]
Fmr. Pioneer Cleaners	1	0.96	Silty Clay (CL)	2.53×10^{-8}	3.12×10^{-10}	$<8.50 \times 10^{-6}$
	2	0.97	Clay (CH)	5.50×10^{-8}	1.24×10^{-10}	N/A
	3	0.87	Clay (CH/CL)	3.50×10^{-9}	8.41×10^{-10}	$<2.20 \times 10^{-3}$
Travis AFB	1	0.70	Silty Clay (CL)	2.68×10^{-8}	1.52×10^{-8}	2.90×10^{-2}
	2	0.78	Clayey Sand (SC)	6.40×10^{-9}	4.63×10^{-9}	1.48×10^{-2}
	3	0.79	Silty Clay (CL/SC)	1.85×10^{-8}	1.08×10^{-8}	3.46×10^{-3}
Tinker AFB	1	1.00	Clayey Silt (ML)	1.60×10^{-9}	6.89×10^{-11}	n/a
	2	1.00	Clayey Silt (ML)	5.44×10^{-9}	9.46×10^{-12}	2.50×10^{-5}
	3	0.97	Clayey Silt (ML)	1.37×10^{-8}	1.13×10^{-10}	2.66×10^{-3}
SPAWAR OTC	1	0.62	Clayey Silt (ML)	NM[5]	3.88×10^{-10}	1.50×10^{-5}
	2	0.96	Clayey Silt (ML/CL)	NM[5]	5.26×10^{-11}	1.40×10^{-5}
	3	0.95	Silty Sand (SM)	NM[5]	2.67×10^{-9}	n/a
NIKE Battery PR-58	1	0.95	Sand (SW)	3.01×10^{-4}	3.87×10^{-9}	1.70×10^{-2}
	2	0.35	Sand (SW)	7.12×10^{-4}	3.25×10^{-8}	1.00×10^{-3}
	3	0.95	Clayey Silt (ML)	9.89×10^{-4}	2.16×10^{-8}	2.80×10^{-4}
Hill AFB	1	1.00	Silty Sand (SM)	5.66×10^{-6}	5.43×10^{-9}	2.50×10^{-2}
	2	0.62	Sand (SP)	3.56×10^{-5}	4.64×10^{-8}	5.20×10^{-2}
	3	0.95	Clayey Silt (ML)	9.88×10^{-6}	1.81×10^{-8}	5.96×10^{-3}
SE Texas Industrial Site	1	0.96	Silty Sand (SM)	2.00×10^{-5}	8.86×10^{-9}	3.93×10^{-2}
	2	0.43	Silty Sand (SM)	5.85×10^{-6}	7.47×10^{-9}	1.78×10^{-1}
	3	0.71	Silty Sand (SM)	4.33×10^{-6}	1.65×10^{-8}	4.84×10^{-1}

(1) Geometric mean of individual laboratory measurements from 2 to 4 depths at cluster location
(2) Value for single vadose zone soil core sample closest to water table at cluster location
(3) Geometric mean of 1 or 2 individual field measurements at cluster location
(4) For measured attenuation factors, geometric mean of attenuation factors measured at cluster location. For upper-bound attenuation factors (i.e., VOC not detected in soil gas samples, attenuation factor shown as $<a \times 10^{-b}$), smallest upper-bound attenuation factor.
(5) NM = No measurement; All samples were fractured upon delivery to the laboratory or were too non-cohesive, preventing the laboratory from analyzing for intrinsic permeability or native hydraulic conductivity.

Table 6.2.9: Relationship between vadose zone soil characteristics and groundwater to deep soil gas attenuation factors: Site-based evaluation

Site	Moisture Content (-)[2]	Predominate Soil Type at Water Table	Native Hydraulic Conductivity (cm/sec)[1]	Field Soil Permeability (cm^2)[3]	Attenuation Factor (GW to Deep SG)[4]
Fmr. Pioneer Cleaners	0.90 +/- 0.063	Clay (CH/CL)	1.5×10^{-8}	1.5×10^{-10}	$<8.5 \times 10^{-6}$
Travis AFB	0.83 +/- 0.094	Silty Clay and Clayey Sand (CL/SC)	1.5×10^{-8}	1.1×10^{-8}	1.0×10^{-2} (1.0×10^{-3} – 2.9×10^{-2})
Tinker AFB	0.96 +/- 0.043	Clayey Silt (ML)	5.7×10^{-9}	4.7×10^{-11}	3.3×10^{-4} ($<2.5 \times 10^{-5}$ – 2.2×10^{-2})
SPAWAR OTC	0.77 +/- 0.18	Clayey Silt (ML)	NM[5]	5.6×10^{-10}	1.5×10^{-5} (1.4×10^{-5} - 1.5×10^{-5})
NIKE Battery PR-58	0.67 +/- 0.28	Sand (SW)	6.3×10^{-4}	1.4×10^{-8}	3.3×10^{-3} (2.8×10^{-4} - 2.1×10^{-2})
Hill AFB	0.79 +/- 0.26	Sand and Silty Sand (SP/SM)	1.2×10^{-5}	1.7×10^{-8}	2.8×10^{-2} (1.7×10^{-2} – 5.2×10^{-2})
SE Texas Industrial Site	0.72 +/- 0.21	Silty Sand (SM)	7.6×10^{-6}	1.0×10^{-8}	0.15 (0.026 - 0.61)

(2) Geometric mean of 7 to 13 individual laboratory measurements
(3) Mean +/- standard deviation for 7 to 13 individual measurements
(4) Geometric mean of 3 to 6 individual field measurements
(5) Geometric mean (range) of 5 to 6 individual groundwater to deep soil gas attenuation factors except for Former Pioneer Cleaners site. At Former Pioneer Cleaners site, attenuation factor calculated based on maximum VOC concentration in groundwater and VOC detection limit in soil gas because no VOCs were detected in any soil gas samples.
(6) NM = No measurement; All samples were fractured upon delivery to the laboratory or were too non-cohesive, preventing the laboratory from analyzing for intrinsic permeability or native hydraulic conductivity.

The relationship between site characteristics and attenuation factor was evaluated both qualitatively and quantitatively. For the statistical analyses, log transformation was used for native hydraulic conductivity, soil permeability, and the attenuation factor because these three parameters were log normally distributed.

Moisture Content: A qualitative evaluation suggests that moisture content is not a good predictor of groundwater to deep soil gas attenuation. Moisture content varied significantly with depth and between clusters at each site. At the depth of interest (i.e., within 2 ft above the water table), moisture content was typically greater that 90%. Although the soil cores with the lowest moisture content were generally coarser grained (e.g., Cluster 2 at NIKE PR-58 and Cluster 2 at Hill AFB), some coarse-grained soil samples had high moisture content (e.g., NIKE PR-58, Cluster 1). Regression analysis confirmed no significant relationship between moisture content and attenuation factor measured at the individual cluster locations ($p=0.14$).

Soil Type (Visual Determination): The sites with silt and clay soils at the water table (Pioneer Cleaners, Tinker AFB, and SPAWAR OTC) generally exhibited lower attenuation factors compared to sites with sandy soils (NIKE PR-58, Hill AFB, and the Industrial Site). Travis AFB appeared to be anomalous with finer-grained soils at the water table but VOC attenuation more consistent with the coarser-grained soil sites.

Native Hydraulic Conductivity (Lab Measurement): There was generally good correlation between native hydraulic conductivity and VOC attenuation. The three sites with the highest native hydraulic conductivity (NIKE PR-58, Hill AFB, and the Southeast Texas Industrial Site) showed lower attenuation (i.e., attenuation factors closer to one). Two sites with low native hydraulic conductivity (Pioneer Cleaners and Tinker AFB) showed higher attenuation (i.e., smaller attenuation factors). Travis AFB was again anomalous with low native hydraulic conductivity but VOC attenuation more consistent with the coarser-grained soil sites. Native hydraulic conductivity could not be measured at the SPAWAR OTC facility. Regression analysis of log native hydraulic conductivity vs. log attenuation factor measured at the individual cluster locations did not show a statistically significant relationship (p=0.26) while the same analysis on a site-by-site basis also did not show a statistically significant correlation (p=0.27). This analysis indicates that laboratory-measured native hydraulic conductivity is not a good method to identify fine-grained soil sites with high groundwater to deep soil gas attenuation.

Soil Permeability (Field Measurement): There was good correlation between soil permeability and VOC attenuation. The four sites with the highest soil permeability (Travis AFB, NIKE PR-58, Hill AFB, and the Industrial Site) showed the higher attenuation factors (i.e., lower attenuation). The three sites with the lowest soil permeability (Pioneer Cleaners, Tinker AFB, and SPAWAR OTC) showed lower attenuation factors (i.e., higher attenuation). Travis AFB was again anomalous with low native hydraulic conductivity but VOC attenuation more consistent with the coarser-grained soil sites. Regression analysis of log soil permeability vs. log attenuation factor measured at the individual cluster locations showed a statistically significant relationship (p=0.004) while the same analysis on a site-by-site basis also showed statistical significance (p=0.04). A two sided t-test indicated a statistically significant difference in attenuation factors between the three sites with lower soil permeability and the four sites with higher soil permeability (p=0.01). This analysis indicates that field-measured soil permeability is a good method to identify fine-grained soil sites with high groundwater to deep soil gas attenuation. The geometric mean groundwater to deep soil gas attenuation factor at the three sites with lower soil permeability was 3.5×10^{-5}. The geometric mean attenuation factor at the four sites with higher soil permeability was 1.9×10^{-2}, a 500-fold difference between the two types of sites.

6.2.4 Summary of Validation of Tier 2 Screening Procedure

The demonstration at seven sites has resulted in validation of the Tier 2 Screening Procedure:

- Although moisture content was not a useful predictor of VOC attenuation, soil type was a useful predictor. Significantly higher VOC attenuation was observed at sites with fine-grained soils at the water table compared to coarse-grained soils at the water table (p = 0.01).
- Visual determination of soil type and laboratory measured hydraulic conductivity provided accurate classification of sites as finer-grained or coarser-grained for 6 of 7 sites. Field-measured soil permeability provided an accurate classification for all 7 demonstration sites.
- A 500-fold difference in VOC attenuation was observed between the fine-grained soil sites and the coarse-grained soil sites with higher attenuation at the fine-grained soil sites.

The specific procedures recommended for implementation of the Tier 2 Screening Procedure are provided in Section 6.4.

6.3 VALIDATION OF TIER 3 INVESTIGATION PROCEDURE

Full validation of the streamlined Tier 3 evaluation requires two key elements: i) observation of differences in VOC distribution between negative pressure and positive pressure conditions that support differentiation between vapor intrusion and background sources of VOCs, and ii) a correlation between cross-foundation pressure gradient measurements and the magnitude of observed vapor intrusion.

For each demonstration building, each of the VOCs commonly detected in indoor and sub-slab samples has been classified as originating primarily from subsurface sources or indoor sources based on i) prior knowledge of VOCs present in subsurface sources, and ii) the sub-slab to indoor attenuation factors measured under negative pressure conditions. Under negative pressure conditions, VOCs originating from subsurface sources are expected to have an attenuation factor of <0.1 while VOCs originating from background sources are expected to have an attenuation factor of >1. The observed attenuation factors for radon (a subsurface tracer) and SF_6 (an indoor tracer) have been used to verify the expected patterns. For all of the demonstration sites, benzene and toluene were identified as originating from above ground sources and detected chlorinated VOCs (PCE, TCE, and/or 1,1-DCE) were identified as originating from subsurface sources.

Based on this preliminary classification, the difference in measured concentrations between negative pressure conditions and positive pressure conditions has been evaluated. The predicted concentration changes are illustrated in Figure 6.3.1.

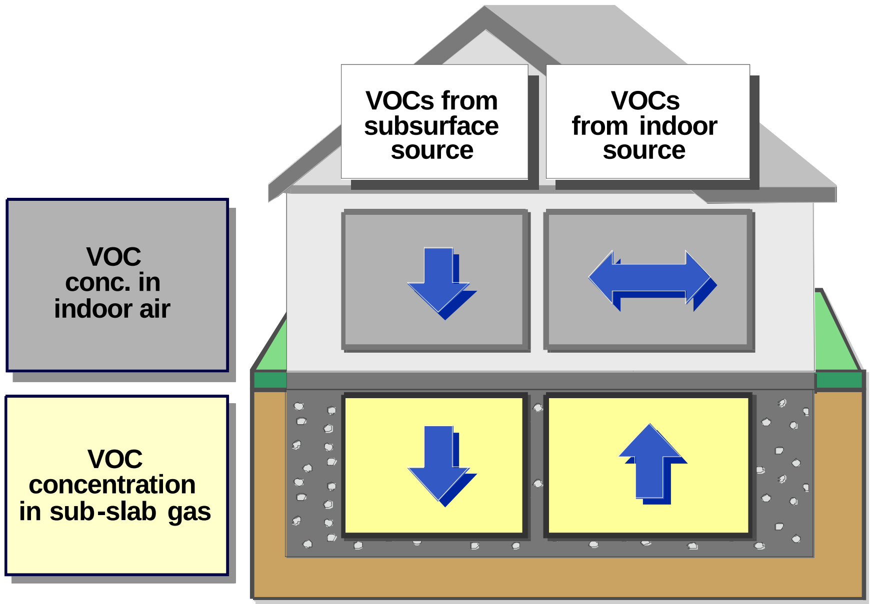

Figure 6.3.1: Predicted change in VOC concentration between negative building pressure and positive building pressure sampling events, under permeable foundation conditions (e.g., the indoor air concentration of VOCs originating from a subsurface source are expected to be lower under positive building pressure conditions compared to negative building pressure conditions)

6.3.1 Analysis of Variance

For the preliminary data analysis, a factorial ANOVA was conducted on the difference in VOC concentration between negative pressure conditions and positive pressure conditions at each measurement location. In order to control for differences in the magnitude of concentration between COCs, the difference was expressed as the RPD in concentration between the negative pressure sampling event and the positive pressure sampling event:

$$RPD = (C_{NP} - C_{PP})/\text{Average}\ (C_{NP}, C_{pp}) \times 100$$

Where:
RPD = Relative percent difference
C_{NP} = COC concentration measured during the negative pressure sampling event
C_{PP} = COC concentration measured during the positive pressure sampling event

Note that the RPD is not represented as an absolute value so that the direction of concentration change (i.e., increase or decrease) between the two pressure conditions is retained. The analytical detection limit was used for non-detect results. For each COC in each demonstration building, this yielded three indoor air measurements and three sub-slab gas measurements. All ANOVA analyses were conducted using the generalized linear model in the MiniTab 13 statistical software package. Full results are provided in Appendix F.

Initial ANOVA Analysis: The initial ANOVA analysis examined the influence of four factors on the observed difference in COC concentration between the negative and positive pressure sampling events. In addition, the interaction between these factors was evaluated:

- Sample Matrix: Indoor air samples vs. sub-slab gas samples (1 degree of freedom);
- COC Source: Above ground vs. subsurface (1 degree of freedom);
- Sample Location: The three sample locations established in each demonstration building (2 degrees of freedom); and
- Demonstration Site: Travis AFB, Jacksonville NAS, Tinker AFB, Hill AFB, and Moffett Field (4 degrees of freedom).

The results from Parris Island were not included in the analysis because the pressure control was not successful at this location. Based on our prediction (Figure 6.3.1), we expected sample matrix, COC source, and the interaction between sample matrix and COC source to be identified as significant factors. Sample location was not predicted to have an effect on the observed difference on COC concentration; however, this factor was included in the initial analysis in order to evaluate the ability of the model to discriminate between factors predicted to have an effect and factors not predicted to have an effect. Demonstration site was identified as a random factor because the differences between sites were not expected to be predictable.

For this initial analysis, sample matrix ($p = 0.005$) and COC source ($p = 0.030$) were identified significant factors. As expected, sample location ($p = 0.446$) was not identified as significant. In addition, none of the interactions between factors was identified as significant except for the combined factors of matrix x location x source x site ($p = 0.044$).

Final ANOVA Analysis: Based on the results of the initial ANOVA analysis, sample location was eliminated as a model factor in order to simplify the model and improve the ability to analyze factor interactions. When sample location was eliminated as a factor, sample matrix and COC source retained the same level of significance but matrix x source x site interaction was also identified as a significant factor ($p = 0.040$).

The results of the ANOVA indicate that the sample matrix, COC source, and matrix x source x site interaction have a significant effect on the observed difference in COC concentration between the negative pressure and positive pressure sampling events. In other words, the change in COC concentration between the negative and positive pressure condition is different for COCs originating from different sources (above ground vs. subsurface) and is different for the different measurement matrix (indoor air vs. sub-slab). This is consistent with the predicted effect of building pressure control illustrated in Figure 6.3.1.

Based on the site-by-site analysis discussed in Section 6.3.2 below, the change in COC concentration in indoor air appeared to be more consistent with the predicted change than the change in COC concentration in sub-slab samples. This observation was supported by additional ANOVA analyses. For ANOVA using only the results for indoor air samples, the source (i.e., above ground vs. subsurface) was identified as the only statistically-significant factor ($p = 0.03$). For ANOVA using only the results for sub-slab air samples, no model parameters were identified as statistically significant (see Appendix F). In other words, the source of the chemical in how the concentration changes in indoor air between induced negative and positive pressure conditions however, this is not a significant factor in how the sub-slab concentration changes.

6.3.2 Site-by-Site Analysis of Results

Although ANOVA is a powerful method to evaluate the statistical significance of specific factors on a large dataset, the method does not evaluate specific trends observed in the data (i.e., did the concentration of COCs originating in the subsurface decrease in indoor air during positive pressure test conditions?). In order to further explore whether the observed COC concentration differences matched the prediction provided in Figure 6.3.1, t-tests were used to evaluate concentration differences at the individual demonstration sites. Table 5.7.5 summarizes the COC concentration measurement results for each demonstration and identifies the cases where the COC concentration under positive pressure conditions was significantly different from negative pressure conditions (t-test, $p < 0.05$). Although the Parris Island demonstration was not considered successful, the results are included for completeness. The observed concentration changes are summarized in Table 6.3.1.

Table 6.3.1: Observed Change in Concentration between Building Test Conditions

Chemical	Source Type	Concentration Change (Baseline to Negative Pressure)		Concentration Change (Negative to Positive)	
		Sub-slab	Indoor	Sub-slab	Indoor
Building 828, Travis AFB					
Benzene	Above ground	NM	NM	No Change	No Change
Toluene	Above ground	NM	NM	No Change	Decrease*
SF_6	Above ground	NM	NM	No Change	Decrease
TCE	Subsurface	NM	NM	No Change	Decrease
Radon	Subsurface	NM	NM	No Change	***Decrease***
Building 103, Jacksonville NAS					
Benzene	Above ground	NM	NM	No Change	***Increase***
Toluene	Above ground	NM	NM	No Change	No Change
SF_6	Above ground	NM	NM	Increase	No Change
PCE	Subsurface	NM	NM	No Change	***Decrease***
TCE	Subsurface	NM	NM	No Change	No Change
Radon	Subsurface	NM	NM	No Change	Decrease
Parris Island New Dry Cleaner (Note, demonstration not considered successful, see Section 4.5.4)					
Benzene	Above ground	NM	NM	Decrease	***Increase****
Toluene	Above ground	NM	NM	Decrease	No Change
SF_6	Above ground	NM	NM	No Change	No Change
PCE	Subsurface*	NM	NM	No Change	***Increase***
Radon	Subsurface	NM	NM	No Change	Increase
Building 102, Tinker AFB					
Benzene	Above ground	NM	NM	Decrease	No Change
Toluene	Above ground	NM	NM	Decrease	***Decrease******
PCE	Subsurface	NM	NM	***Decrease***	Decrease*
Radon	Subsurface	NM	NM	Decrease	No Change
ASU Research House, Hill AFB (Round 1)					
Benzene	Above ground	Increase	No Change	Decrease	No Change
Toluene	Above ground	No Change	***No Change***	Decrease	***Increase****
SF_6	Above ground	Decrease	***Decrease***	Increase	No Change
DCE	Subsurface	Increase	Increase	Decrease	Decrease
TCE	Subsurface	Increase	No Change	Decrease	Decrease
Radon	Subsurface	No Change	Increase	No Change	Decrease

Table 6.3.1: Observed Change in Concentration between Building Test Conditions (Continued)

Chemical	Source Type	Concentration Change (Baseline to Negative Pressure)		Concentration Change (Negative to Positive)	
		Sub-slab	Indoor	Sub-slab	Indoor
ASU Research House, Hill AFB (Round 2)					
Benzene	Above ground	***Increase***	No Change	No Change	No Change
Toluene	Above ground	Increase	No Change	Decrease	No Change
SF_6	Above ground	Decrease	***Decrease***	Increase	No Change
DCE	Subsurface	Increase	Increase	Decrease	Decrease
TCE	Subsurface	Increase	No Change	Decrease	Decrease
Radon	Subsurface	No Change	Increase	No Change	Decrease
Building 107, Moffett Field (Round 1)					
Benzene	Above ground	Decrease	***No Change***	No Change	Increase*
Toluene	Above ground	No Change	***No Change***	No Change	Increase
SF_6	Above ground	No Change	***Decrease***	Increase	Increase
PCE	Subsurface	No Change	No Change	No Change	***Decrease***
TCE	Subsurface	Increase	***No Change***	No Change	***Decrease***
Radon	Subsurface	No Change	No Change	No Change	***Decrease***
Building 107, Moffett Field (Round 2)					
Benzene	Above ground	No Change	***No Change***	No Change	No Change
Toluene	Above ground	No Change	Increase	No Change	No Change
SF_6	Above ground	Decrease	***Decrease***	Increase	No Change
PCE	Subsurface	Increase	No Change	No Change	***Decrease***
TCE	Subsurface	No Change	***No Change***	No Change	***Decrease***
Radon	Subsurface	No Change	No Change	No Change	Decrease

Increase = Average concentration during positive pressure condition more than 150% of the average concentration during negative pressure condition. Decrease = Average concentration during positive pressure condition less than 50% of the average concentration during negative pressure condition. No Change = Average concentration during positive pressure condition between 50% and 150% of the average concentration during negative pressure condition. * = Similar change in concentration observed in ambient air samples. ***Bold, underlined, italic*** = statistically significant change based on paired t-test.

Because the Tier 3 demonstration at the Parris Island New Dry Cleaner Facility was not successful, the discussion of the results focuses on the remaining five demonstration buildings.

The comparison between predicted and observed change in concentration between the induced negative and positive pressure testing conditions was based on two factors: i) whether the concentration trend matched the prediction, and ii) whether the change was statistically significant. For chemicals with an above ground source (i.e., benzene, toluene, and SF_6), the change in concentration in indoor air between negative and positive pressure conditions matched the prediction (i.e., no change) for 12 out of 20 cases. For four of the remaining eight cases, the increase or decrease in indoor air concentration was matched by a similar change in ambient air concentration indicating that the change was independent of the change in building pressure condition. For chemicals with a subsurface source (i.e., the chlorinated VOCs), the observed concentration trend in indoor air matched the prediction (i.e., decrease) in 17 of 19 cases, however, the change was statistically significant in only 7 cases.

For chemicals with an above ground source, the change in concentration in the sub-slab matched the prediction (i.e., increase in concentration) in only five out of 20 cases. For chemicals with a subsurface source, the concentration change in the sub-slab matched the prediction (i.e., decrease) in only six of 19 cases.

The clearest evidence of the utility of building pressure control for evaluation of vapor intrusion is provided by the measurement of radon concentrations in indoor air. At four of the five buildings with successful pressure control, radon concentrations in indoor air were above atmospheric concentrations during negative building pressure and decreased to atmospheric concentrations during positive building pressure. In the fifth building (at Tinker AFB), the radon concentration was equal to atmospheric concentrations during both sampling events indicating an absence of vapor intrusion under all conditions (see Figure 6.3.2). For all five of these buildings, the indoor concentration of other COCs with subsurface sources (i.e., the chlorinated VOCs), was either i) very low (i.e., $< 1 \mu g/m^3$) under both the negative pressure condition and the positive pressure condition, or ii) the concentration was much lower under the positive pressure condition compared to the negative pressure condition, matching the pattern observed for radon.

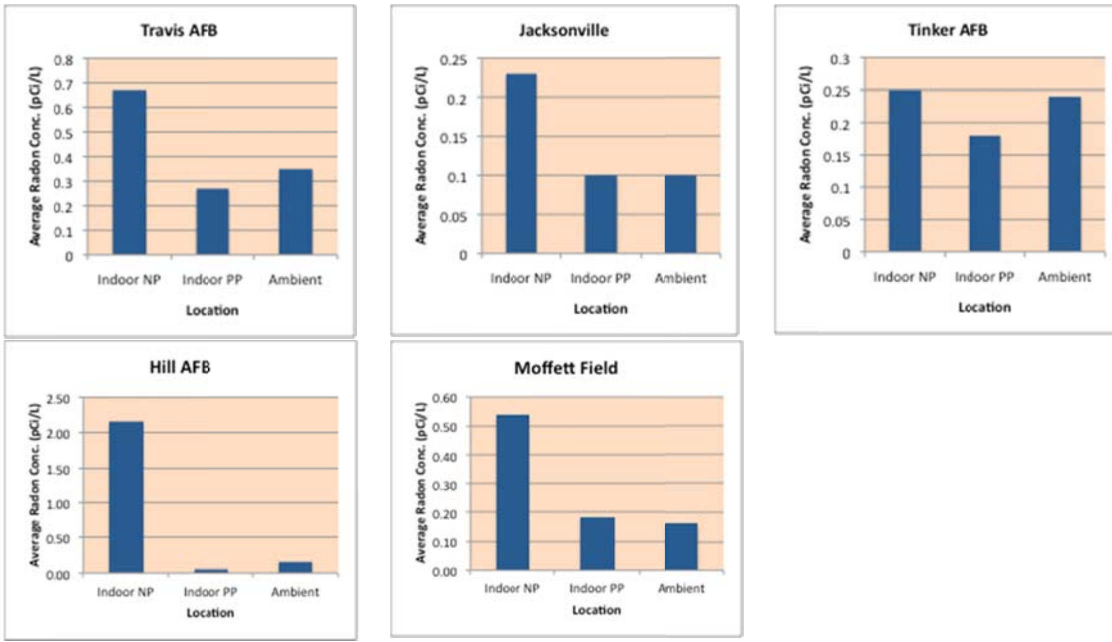

Figure 6.3.2: Effect of Building Pressure Control on Concentration of Radon in Indoor Air

<u>Finding</u>: The ANOVA indicates that positive vs. negative building pressure does have a statistically significant effect on the distribution of COCs in indoor air and below the building foundation and that the response is dependent on the source of the COC (i.e., subsurface source vs. above-ground source). Two focused ANOVA using only indoor air data and only sub-slab data indicate that the statistically-significant effect is due to the distribution of COCs in indoor air rather than below the building foundation. This finding is supported by evaluation of the individual site data which indicates that the predicted changes in COC concentration illustrated in Figure 6.3.1 generally occur in indoor air but does not typically occur below the building foundation.

6.3.3 Correlation between Cross-Foundation Pressure Gradients and Vapor Intrusion

A second aspect of the hypothesis for the Tier 3 demonstration is that the magnitude of the cross-foundation pressure gradient induced by the building pressurization will provide an indication of the building foundation permeability. This, in turn, will provide an indication of the potential for future vapor intrusion impacts. In a building with a more permeable foundation, induction of negative or positive building pressure will yield only a small cross-foundation pressure gradient. However, in a building with a less permeable foundation, induction of negative or positive building pressure will yield a larger cross-foundation pressure gradient. The building foundation permeability was evaluated by comparing the cross-foundation pressure gradient to the pressure gradient across the building envelope (Table 5.7.6).

A Fisher Exact test was used to determine whether there was a statistically significant correlation between foundation permeability and magnitude of vapor intrusion. This test was conducted using the 3 x 3 matrix shown in Table 6.3.2 and the 2 x 2 matrix shown in Table 6.3.3. In both cases, there was no significant correlation ($p = 0.3$ and $p=0.5$). Although the statistical power of these tests was low due to the small sample size, a qualitative evaluation of the results supports the conclusion that a field measurement of foundation permeability is not likely to provide a meaningful evaluation of the potential for vapor intrusion.

Table 6.3.2: Matrix of Foundation Permeability and Magnitude of Vapor Intrusion

Number of Sites with Each Classification Combination (Six Sites Total)				
	Magnitude of Vapor Intrusion			
Foundation Permeability Classification		High	Medium	Low
	High	-	1	2
	Medium	-	-	1
	Low	1	1	-

Table 6.3.3: Secondary Matrix of Foundation Permeability and Magnitude of Vapor Intrusion

Number of Sites with Each Classification Combination (Six Sites Total)			
	Magnitude of Vapor Intrusion		
Foundation Permeability Classification		High	Low
	High	1	2
	Low	2	1

<u>Finding</u>: *The demonstration dataset does not show a statistically significant correlation between foundation permeability (as determined by measurement of cross-foundation pressure gradients) and vapor intrusion.*

6.3.4 Other Analysis of Tier 3 Demonstration Results

In addition to the performance assessment envisioned in the Demonstration Plan, the Tier 3 demonstration dataset supports the following additional evaluations and observations.

<u>6.3.4.1. Evaluation of Reproducibility</u>: In order to evaluate the reproducibility of the Tier 3 investigation procedure, the Tier 3 demonstration was conducted twice in each of the two final demonstration buildings: ASU Research House, Hill AFB and Building 107, Moffett Field. As shown in Table 5.7.5 and Figure 6.3.3, the change in COC concentrations in sub-slab samples and indoor air samples was generally similar over the two rounds of testing. Specifically, the change in COC concentrations in indoor air between the negative pressure condition and the positive pressure condition was the same between the two rounds. As a result, the interpretation of the results with respect to the sources of the detected chemicals (i.e., above ground vs. subsurface) is the same for the two rounds. This demonstration of reproducibility serves to increase confidence that the Tier 3 investigation procedure provides reliable results.

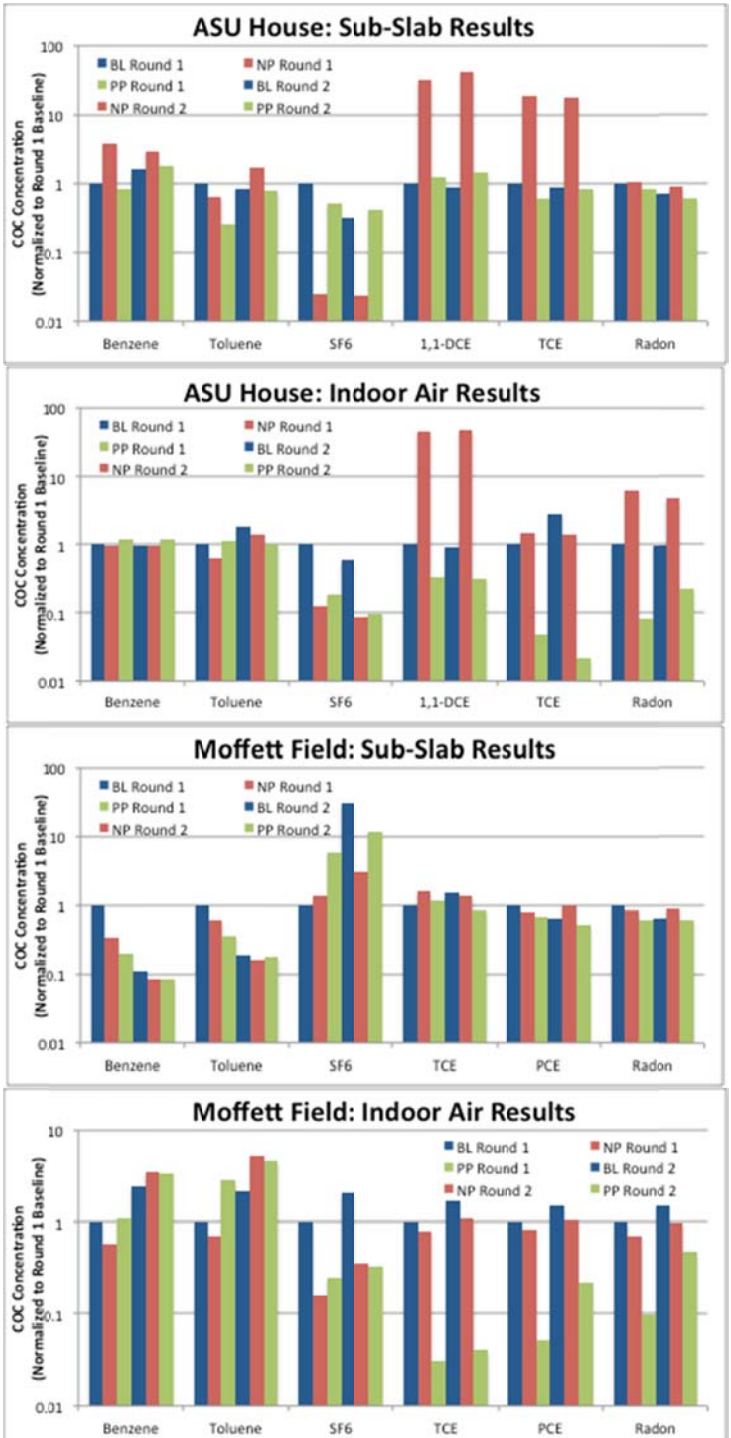

Figure 6.3.3: Comparison of Concentration Results over Two Rounds of Testing

<u>*6.3.4.2. Control of Temporal Variability in Vapor Intrusion:*</u> For some buildings (e.g., ASU Research House, Hill AFB), vapor intrusion is episodic. For this type of building, a single standard testing event may not accurately identify a true vapor intrusion problem. As a result, several standard testing events may be required to confirm an absence of vapor intrusion.

The Tier 3 demonstration dataset indicates that building depressurization can be used to evaluate the potential for episodic vapor intrusion during a single testing event. For the ASU Research House, the baseline sampling results showed an absence of vapor intrusion during this testing event. However, the sample results from the controlled negative pressure condition showed clear vapor intrusion indicating a potential for vapor intrusion to occur under some building operating conditions. At a less well characterized building, additional investigation would be required to evaluate whether vapor intrusion would occur under any actual building operating conditions. However, the results from the controlled negative pressure condition would serve to flag the building as high priority for additional investigation. In contrast, an absence of vapor intrusion under controlled negative pressure conditions would serve to provide a high level of confidence that there is little to no potential for episodic vapor intrusion.

6.3.4.3. Limitations of Sub-Slab Samples for Evaluation of Vapor Intrusion: The current standard building-specific vapor intrusion sampling program uses indoor air and sub-slab sample results to evaluate the presence or absence of vapor intrusion using a multiple lines of evidence data evaluation approach (ITRC, 2007). A key line of evidence is the detection of COCs in sub-slab samples at concentrations at least 10 times those detected in indoor air. Based on the dilution and attenuation that occurs between the subsurface and indoor air, vapor intrusion is considered unlikely to result in COC concentrations in indoor air that are greater than 10% of the sub-slab concentrations. Higher than expected concentrations of COCs in indoor air is considered strong evidence that indoor or ambient sources are contributing to the concentrations in indoor air.

The Tier 3 demonstration dataset illustrates the limitations of this line of evidence for the evaluation of vapor intrusion. At Building 107, Moffett Field, the sub-slab concentrations of TCE and PCE were similar to the indoor air concentration during all three test conditions (baseline, negative pressure, and positive pressure) while the radon concentrations were 500 to 1,000 times higher than in indoor air. Using the standard lines of evidence approach, this would be considered strong evidence of an indoor source of TCE and PCE. However, the results from the controlled negative and positive pressure test conditions clearly showed that TCE, PCE and radon all originated from subsurface sources (i.e., the concentrations of all three COCs were elevated in indoor air during the negative pressure condition but equivalent to ambient concentrations under the positive pressure condition).

6.3.4.4. Time Required for Indoor Air Concentrations to Respond to Change in Pressure Condition: For the Tier 3 field demonstration program, each pressure condition was maintained for at least 12 hours prior to initiation of sample collection in order to allow the VOC concentrations in indoor air to respond to the change in building pressure. If the indoor air is well mixed (i.e., if the building behaves like a continuous-stir tank reactor), then three air exchanges should be sufficient to achieve VOC concentrations within approximately 10% of the new steady-state conditions. For the five buildings where air exchange rates were measured, the air exchange rates under the pressure control conditions ranged from 14 day^{-1} to 80 day^{-1}. For these buildings, three air exchanges would occur within one to five hours after initiation of the pressure control condition. As a result, 12 hours should have been more than sufficient to attain steady-state conditions even in the absence of complete mixing. This theoretical analysis assumes that VOC sinks in the subsurface and/or building do not cause a lag in the response time.

At the ASU Research House, supplemental indoor air analyses were conducted using the field portable HAPSITE GC/MS at indoor air sample location IA-2 at a frequency of every 1 to 2 hours for the duration of the demonstration (see Appendix A.6). The results from these supplemental analyses allow a direct evaluation of the time required for VOC concentrations in indoor air to respond to a change in the building pressure condition. The relationship between pressure condition and VOC concentration at sample point IA-2 is shown in Figure 6.3.4. Although both TCE and 1,1-DCE exhibit temporal variability over the course of the demonstration, the concentration changes induced by changes in building pressure appear to occur within two to four hours after the change in pressure (see Figure 6.3.4 and Table A.6.11). This response time is consistent with the theoretical analysis in the absence of a lag time. For this building, the HAPSITE data supports the prediction that approximately three air exchanges is sufficient for VOC concentrations in indoor air to respond to a change in building pressure.

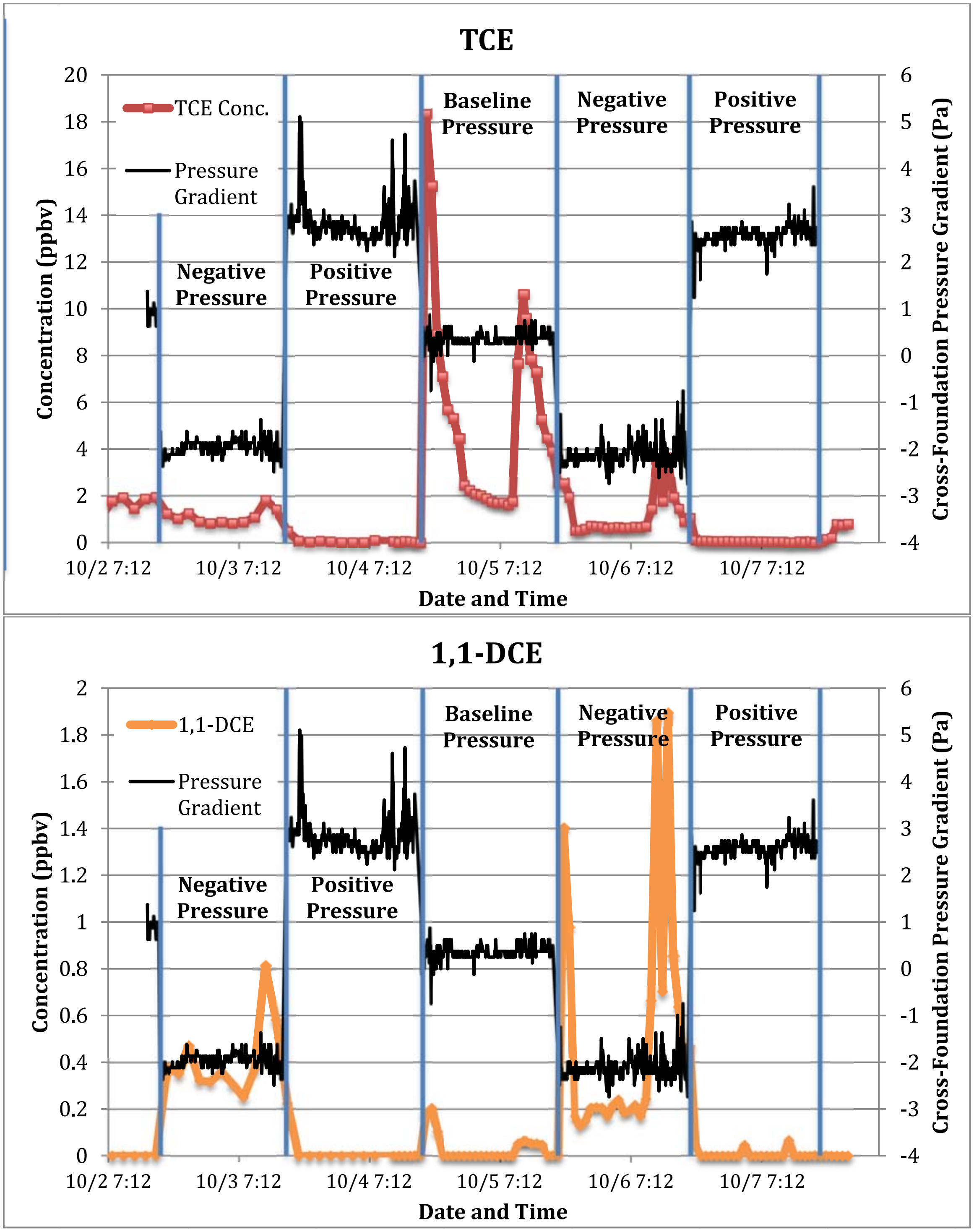

Figure 6.3.4: Effect of Building Pressure Control on Concentration of VOCs in Indoor Air Sample Point IA-2 at ASU Research House.

6.3.5 Summary of Validation of Tier 3 Investigation Procedure

The demonstration in six buildings has resulted in validation of the Tier 3 Investigation Procedure:

- ANOVA conducted on the entire Tier 3 demonstration dataset shows that the control of building pressure provides the ability to distinguish between COCs originating from subsurface sources vs. COCs originating from above ground sources based on the change in concentration in indoor air between the controlled negative pressure condition and the controlled positive pressure condition ($p = 0.03$).
- For the six demonstration buildings, the change in COC concentration in indoor air between the controlled negative pressure condition and the controlled positive pressure condition matched the predicted change for subsurface COCs (i.e., decrease in concentration) for 17 of 19 cases and matched the predicted change for above ground COCs (i.e., no change or change matching the change in ambient concentrations) in 16 of 20 cases.

Some of the specific hypotheses were not validated:

- The changes in COC concentration in sub-slab samples did not generally match the prediction.
- There was no clear correlation between measured foundation permeability and the magnitude of vapor intrusion in the six demonstration buildings.

The validation dataset supports some additional findings not discussed in the original demonstration plan:

- Implementation of the investigation procedure twice in each of two demonstration buildings showed that the procedure yields reproducible results.
- The Tier 3 Investigation Procedure can be used to control for temporal variability in buildings with episodic vapor intrusion (e.g., ASU Research House, Hill AFB).
- The Tier 3 Investigation Procedure can be used to accurately identify vapor intrusion in buildings where the standard lines of evidence approach would incorrectly suggest and indoor source (e.g., Building 107, Moffett Field).

The specific procedures recommended for implementation of the Tier 3 Field Investigation Procedure are provided in Section 6.5.

6.4 TIER 2 SCREENING CRITERIA AND PROCEDURES

The goal of the field demonstration for the Tier 2 screening procedure was to produce a validated procedure to apply to other sites with vapor intrusion concerns. The validation of the procedure was addressed in Section 6.2. This section addresses routine application of the Tier 2 screening procedure at vapor intrusion investigation sites. The Tier 2 screening procedure involves i) identification of sites with fine-grained soils at the water table, and ii) application of an adjustment factor to the Tier 1 screening criteria to account for the higher VOC attenuation observed at these sites.

6.4.1 Identification of Sites with Fine-Grained Soils at the Water Table

The presence of fine-grained soil at the water table can be determined using one of two methods: i) visual inspection of soil cores, or ii) field measurement of soil permeability.

- Visual inspection of soil cores: Boring logs generated during the installation of groundwater monitoring wells or soil boring can be used to determine the presence of fine-grained soils at the water table. When using this method, a site should be classified as fine-grained if the soils within two ft above the water table are predominately silts or clays. This method provided an accurate classification of soil type at six of the seven demonstration sites.

- Soil permeability: Soil permeability can be measured in the field as described in Section 5.5.1 of this report. Calculation methods are described in Appendix C. When using this method, a site with a geometric mean soil permeability of less than 1×10^{-9} cm^2 should be classified as a fine-grained soil site. This method proved accurate at all seven demonstration sites.

The choice between the simpler and less expensive, but potentially less accurate classification method (i.e., visual inspection) vs. the more complex, but potentially more accurate classification method (i.e., field measurement) should be based on a consideration of other uncertainty associated with the pathway evaluation. If VOC concentrations are only slightly above Tier 1 screening levels or if the visual classification is obvious based on identification of a thick clay confining layer at the water table, then field measurement of soil permeability is less necessary.

6.4.2 Application of Adjustment Factor to Tier 1 Groundwater Screening Criteria

As discussed in Section 6.2, sites with fine-grained soils at the water table were found to exhibit an average of 500 times more attenuation of VOCs from groundwater to deep soil gas. Based on this observation, Tier 1 groundwater screening criteria for the vapor intrusion pathway that have been established to be protective at all types of sites can be adjusted upward by 100 times based on the determination that a site has fine-grained soils at the water table. We recommend an adjustment of 100 times rather than 500 times as a conservative measure to account for potential variability in groundwater to deep soil gas attenuation not characterized during the demonstration. An example application is as follows:

> If the Tier 1 Groundwater Screening Concentration for PCE were 1 μg/L (e.g., NJDEP, 2007), then the Tier 2 screening value for a site with fine-grained soil at the water table would be 100 μg/L.

The adjustment factor is intended to be applied to generic Tier 1 screening criteria that do not already include a consideration of soil type. The adjustment is not intended to be applied to screening criteria that already account for soil type.

The resulting Tier 2 screening concentrations should be compared to VOC concentration measurements from conventional monitoring wells (i.e., ≥5 ft well screens) screened at the top of the shallowest water-bearing unit. The screening concentrations are not applicable for grab samples or samples collected directly from the top of the water-bearing zone using very short well screens. The VOC concentrations in these samples may be biased low due to the loss of VOCs to the vadose zone.

6.5 TIER 3 INVESTIGATION PROCEDURE

The goal of the field demonstration for the Tier 3 investigation procedure was to produce a validated procedure for application of a streamlined building investigation program that provides a reliable determination of the presence or absence of a vapor intrusion concern for that building. The actual investigation procedure is less extensive that the program implemented to validate the procedure. For the validation, additional data was required to fully evaluate the procedure performance. The streamlined Tier 3 evaluation procedure consists of procedures for i) control of building pressure to create negative and positive building pressure conditions, ii) a VOC and tracer gas sampling program, iii) pressure gradient measurements, and iv) data interpretation methods.

6.5.1 Overview of Tier 3 Investigation Procedure

Conceptually, sampling of indoor air is the most direct method to evaluate the presence or absence of vapor intrusion at a specific building. However, sampling of indoor air during a single sampling event has two key limitations: i) the sampling event might not be scheduled during “worst case” vapor intrusion conditions when flow of soil gas into the building is maximized, and ii) VOCs detected in indoor air samples cannot easily be attributed to a specific source (i.e., vapor intrusion or an indoor source). Currently, some state regulatory guidance documents recommend multiple indoor sampling events or building sampling only during specific weather conditions (i.e., during the heating seasons) in order to characterize “worst case” vapor intrusion conditions. In addition, most regulatory guidance documents recommend use of “multiple lines of evidence” to distinguish between vapor intrusion and indoor sources of VOCs.

For buildings with concrete foundations, the streamlined Tier 3 building sampling procedure uses the manipulation of building pressure to “turn on” and “turn off” vapor intrusion (see Figure 6.5.1). Indoor air samples collected under controlled negative building pressure conditions are used to characterize indoor air quality under conditions of maximum soil gas entry into the building while indoor air samples collected under controlled positive pressure building conditions are used to characterize indoor air quality in the absence of soil gas entry. As a result, VOCs detected in indoor air under positive building pressure conditions are generally representative of sources other than vapor intrusion. During a single 3-day sampling event, this streamlined evaluation procedure documents indoor air quality under a range of building pressure conditions allowing the determination of the impact of vapor intrusion and other VOC sources on indoor air quality.

Controlled <u>negative</u> building pressure: Vapor intrusion is "on"

Controlled <u>positive</u> building pressure: Vapor intrusion is "off"

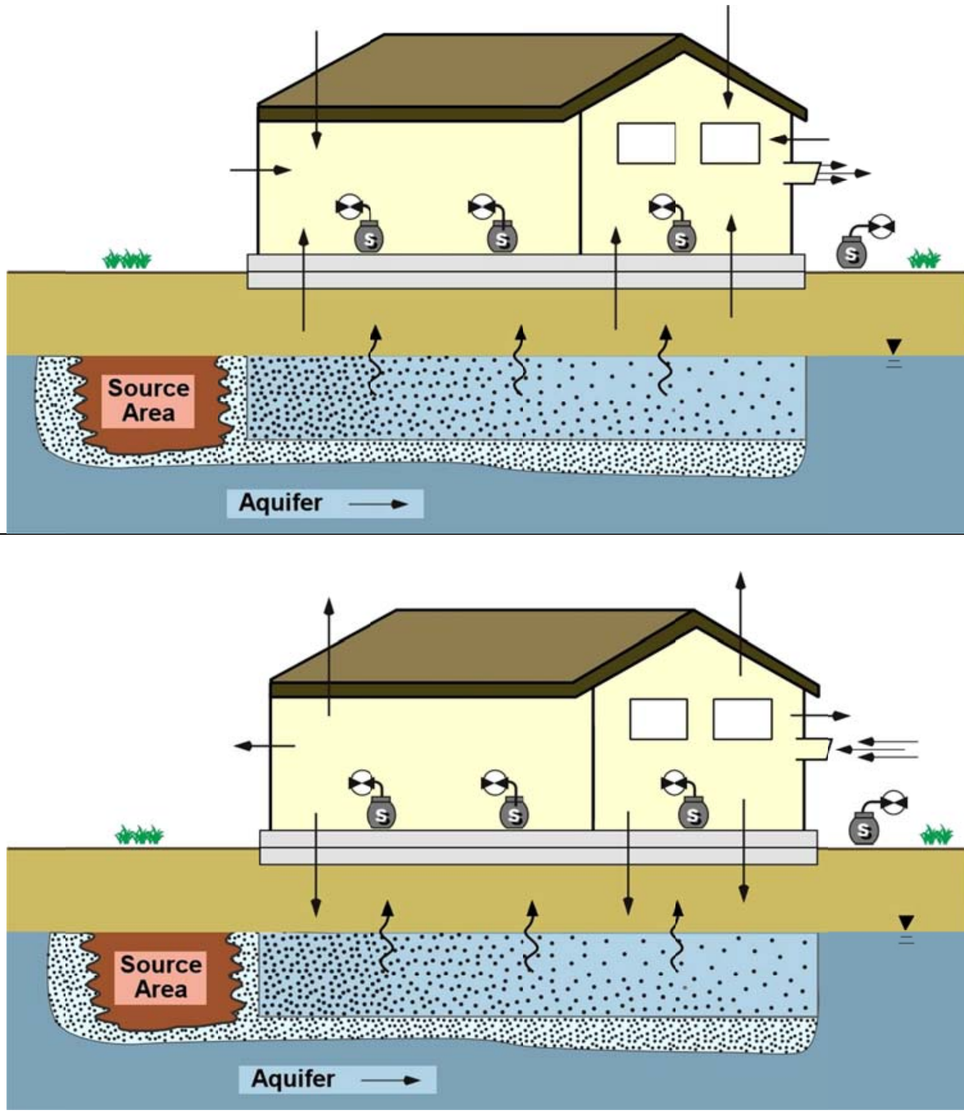

Figure 6.5.1: Conceptual illustration of building pressure control for the building-specific evaluation of vapor intrusion

6.5.2 Method Implementation

<u>Sampling Program</u>: The Tier 3 pressure control method requires measurement of indoor and ambient radon concentrations under baseline conditions and indoor and ambient radon and VOC concentrations under negative building pressure conditions and positive building pressure conditions over a 3-day period (see Table 6.5.1 and Figure 6.5.2).

Table 6.5.1: Tier 3 Pressure Control Method Sampling Program: Routine Application

Pressure Condition	Matrix	Number of Samples	Analyte	Location
Baseline	Indoor air	1	Radon	Open area on lowest building level.
Negative Pressure	Indoor air	1 -3	Radon, VOCs	Open area on lowest building level plus up to two additional samples based on building layout.
	Ambient air	1	Radon, VOCs	Upwind location
Positive Pressure	Indoor air	1 -3	Radon, VOCs	Open area on lowest building level plus up to two additional samples based on building layout.
	Ambient air	1	Radon, VOCs	Upwind location

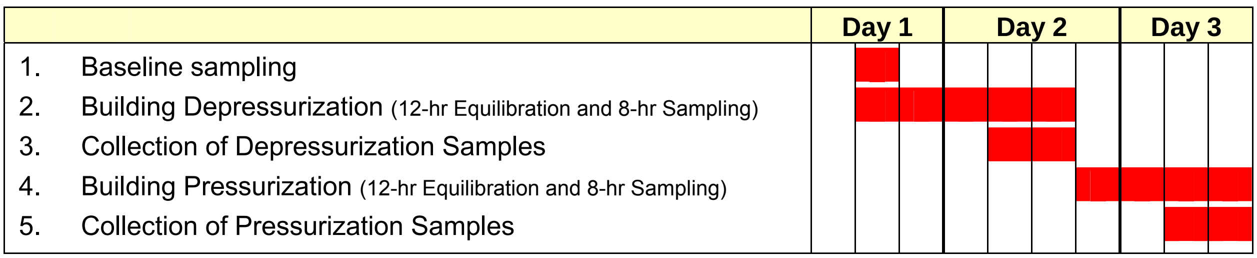

Figure 6.5.2: Pressure Control Method Field Schedule: Routine Application

Data Interpretation: The magnitude of vapor intrusion in the building is evaluated by comparing the VOC concentration in indoor air measured under negative building pressure to the VOC concentration in indoor air measured under positive building pressure conditions. The difference in VOC concentration between the two test conditions is the VOC concentration attributable to vapor intrusion. For example, if the concentration of PCE in indoor air is 5 $\mu g/m^3$ under negative building pressure conditions and 1 $\mu g/m^3$ under positive building pressure conditions, then the PCE in indoor air under negative pressure conditions is primarily attributable to vapor intrusion. Based on the variability typically observed between the indoor air measurement locations, the resulting dataset is usually not suitable for a quantitative determination of impact of vapor intrusion (i.e., for the PCE example, an estimate that 80% of the PCE in indoor is attributable to vapor intrusion would have a large uncertainty). However, the resulting dataset is usually sufficient for identification of the primary source of each COC in indoor air).

The radon results are used as a positive control tracer for the movement of soil gas into the building. Although radon concentrations in soil gas are higher in some regions than in others, the radon concentration in sub-slab soil gas is typically high enough to be used as a tracer for the movement of soil gas through the building foundation (i.e., radon concentration in soil gas is typically > 100 pCi/L). As a result, when soil gas is entering the building through the building foundation, the concentration in indoor air will be higher than the concentration in ambient air. Thus, the radon results will be used to verify that soil gas entry into the building is occurring under negative pressure conditions and eliminated under positive pressure conditions. The interpretation of the radon results is illustrated in Table 6.5.2.

Table 6.5.2: Use of Radon Concentration Data to Verify Method Performance

Comparison	Condition	Interpretation
Radon Concentration in Indoor Air: Baseline vs. Negative Pressure	Baseline concentration ≤ negative pressure condition	Negative pressure condition has maximized vapor intrusion
	Baseline concentration > negative pressure condition	Increased air exchange associated with building depressurization may have caused dilution of vapor intrusion impact
Radon Concentration under Positive Pressure: Indoor vs. Ambient	Concentration in indoor air = concentration in ambient air	Positive pressure condition has "turned off" vapor intrusion
	Concentration in indoor air > concentration in ambient air	Some vapor intrusion may be occurring under positive pressure conditions

7.0 COST ASSESSMENT

The primary objectives of this demonstration study were to develop simple procedures for i) Tier 2 site-specific vapor intrusion screening based on soil characteristics, and ii) Tier 3 limited building-focused field investigation. In the current, typical state of practice, vapor intrusion investigations are iterative, costly, and often produce ambiguous results. Streamlining and validating investigation procedures for Tier 2 and 3 vapor intrusion investigations, therefore, has both technical and cost benefits.

The following sections summarize costs for the field demonstrations included in this ESTCP project. It is important to note that the field demonstrations included additional tasks and associated costs in order to validate the Tier 2 screening and Tier 3 investigation procedures. The cost for standard application of the validated procedures is significantly less because less field data required to apply the validated procedures is less than the data needed for the validation. Representative costs for the demonstration program are presented in Section 7.1. Estimated costs for routine application of the validated procedures are presented in Section 7.2, and cost drivers are discussed in Section 7.3.

7.1 COST MODEL (COST OF FIELD DEMONSTRATION PROGRAM)

Both the Tier 2 screening and Tier 3 investigation procedures are fundamentally site characterization methods. As such, key cost components of the demonstration were i) sample point installation, ii) sample collection and analysis, and iii) data analysis and reporting. Note that costs for standard activities such as planning and project management are not included in the summaries because these activities were not unique to the demonstration.

7.1.1 Costs for Demonstration of Tier 2 Screening Procedure

The Tier 2 demonstration costs for contractors and materials are provided in Table 7.1.1 and are based on the seven sites: 1) Former Pioneer Dry Cleaner, Texas; 2) Travis AFB, California; 3) Tinker AFB, Oklahoma; 4) Hill AFB, Utah; 5) SPAWAR OTC, California; 6) NIKE Battery Site, Rhode Island; and 7) Industrial Site, Southeast Texas. The Tier 2 demonstration was planned but not completed at Parris Island Marine Base because of the presence of groundwater at a depth of less than 5 ft bgs.

Typical consultant labor requirements for implementation of a Task 2 field demonstration event are provided in Table 7.1.2. Representative unit costs for individual elements of the Tier 2 demonstration program are presented in Table 7.1.3.

Table 7.1.1: Costs for Demonstration of Tier 2 Screening Method (Not Including Labor)

Cost Element	Data Tracked For Demonstration	Typical Cost	Range of Costs Over Demonstration Sites
1. Project planning and preparation	None (standard practice)	N/A	N/A
2. Installation of monitoring points by direct push technology (5 wells and 5 SG points in 3 clusters)	Contractor Costs	$12,400	$10,200 - $16,300
3. Sample collection	Materials, consumables, equipment rental, shipping*	$2,300	$332 - $3,900
4. Sample analysis	Geotechnical samples (typ. 3-5 samples / cluster)	$5,700	$2,800 - $7,800
	Groundwater and air/gas samples *	$4,700	$3,000 - $6,300
5. Data evaluation and reporting	Consumables*	$100	$100
Total Typical Third Party and Materials Costs		$25,200	

Note: Asterisks (*) note costs from Tier 2 only sites.

Table 7.1.2: Typical Consultant Labor Requirements for Tier 2 Demonstration

Demonstration Element	Labor Hours		
	Senior Project Scientist/Engineer	Project Scientist/Engineer	Technician
1. Project planning and preparation	10 – 15 hours	25 – 35 hours	4 – 8 hours
2. Oversight and installation of monitoring points (5 wells and 5 SG points in 3 clusters)	None	24 – 40 hours	None
3. Sample collection	None	16 – 24 hours	16 – 24 hours
4. Data evaluation and reporting	10 – 15 hours	25 – 30 hours	None
Total Labor (hours)	25 hours	110 hours	26 hours

Table 7.1.3: Representative Unit Costs for Tier 2 Demonstration

Cost Element	Sub Category	Representative Unit Cost	Representative Unit
Installation of monitoring points by direct push technology	Set of Piezometers and Soil Gas Points	$4,000	Per cluster of 10 monitoring points
Sample analysis	Geotechnical samples	$200	Per core sample
	Groundwater samples by VOCs by Method 8260	$100	Per water sample
	Air/gas sample by Method TO-15 at off-site lab	$175	Per air/gas sample
	SF_6 by NIOSH Method 6602	$75	Per air/gas sample
	Air/gas sample radon analysis at off-site lab	$100	Per air/gas sample

Note: Representative costs include all material and labor costs for contractors and laboratory. They do not include labor costs for consultant oversight, field work, sample collection, data analysis or reporting.

7.1.2 Costs for Demonstration of Tier 3 Field Investigation Program

The Tier 3 demonstration costs are based on the Tier 3 demonstration sites: 1) Travis AFB, California; 2) NAS Jacksonville, Florida; 3) Parris Island Marine Base, South Carolina; 4) Tinker AFB, Oklahoma; 5) Hill AFB, Utah; and 6) Moffett Field NAS, California. The Tier 3 demonstration was completed a total of eight times, with the Hill AFB and Moffett Field NAS buildings each tested twice. Consumable and third party costs for implementation of the Task 3 field program are summarized in Table 7.1.4. Typical labor requirements for implementation of a Task 3 field demonstration event are provided in Table 7.1.5. Representative unit costs for individual elements of the Tier 3 demonstration program are presented in Table 7.1.6.

Table 7.1.4: Costs for Demonstration of Tier 3 Field Investigation Procedure (Not Including Labor)

Cost Element	Data Tracked For Demonstration	Typical Cost	Cost Range
1. Project planning and preparation	None (standard practice)	N/A	N/A
2. Building preparation and field screening, including installation of monitoring points through foundation (typically 3 sub-slab points per building), and sample collection	Materials, consumables, equipment rental*	$2,000	$1,000 - $3,500
3. Sample analysis	Air/gas samples*	$7,400	$6,500 - $8,200
	Radon*	$2,400	$1,700 - $3,600
4. Data evaluation and reporting	Consumables	$100	$100
	Total Typical Third Party and Materials Costs	$11,900	

Note: Asterisks (*) note costs from Tier 3 only sites. Equipment rental did not include differential pressure recorders already owned by GSI (purchase cost $1,500).

Table 7.1.5: Typical Consultant Labor Requirements for Tier 3 Demonstration

Demonstration Element	Labor Hours	
	Senior Project Scientist/Engineer	Project Scientist/Engineer
1. Project planning and preparation	10 – 15 hours	25 – 35 hours
2. Pressure control and sampling field program	24 – 32 hours	24 – 32 hours
3. Data evaluation and reporting	10 – 15 hours	25 – 30 hours
Total Labor (hours)	53 hours	86 hours

Table 7.1.6: Representative Unit Costs for Tier 3 Demonstration

Cost Element	Sub Category	Representative Unit Cost	Representative Unit
Installation of monitoring points	Soil gas point [2]	$100	Per building
Building preparation and field screening	Equipment rental [3]	$225	Per building
Sample analysis	Air/gas sample by Method TO-15 at off-site lab	$270 ($175 analysis + $90 lab equipment rental)	Per air/gas sample
	SF_6 by NIOSH Method 6602	$75 (cost for analysis only; there is no additional lab equipment cost because sample is extracted from the TO-15 canister)	Per air/gas sample
	Air/gas sample radon analysis at off-site lab	$110 ($100 analysis + $10 PVF bag)	Per air/gas sample

Note: 1) Representative costs include all material and labor costs for contractors and laboratory. They do not include labor costs for consultant oversight, field work, sample collection, data analysis or reporting. 2) Unit cost estimate includes $50/day rental of hammer drill for 1 day and materials for sub-slab point construction. 3) Unit cost estimate assumes $75/day total for rental of floor fan and differential pressure recorder, for 3 days.

7.2 COST ANALYSIS (COST FOR IMPLEMENTATION OF TIER 2 AND TIER 3 PROCEDURES)

The costs summarized in Section 7.1 apply to the Tier 2 and Tier 3 demonstrations and included extensive samples and activities required for validation of the proposed procedures. As discussed in Section 6.4 and 6.5, routine application of the validated procedures will be less costly. The cost estimates for implementation of the Tier 2 and Tier 3 procedures assume implementation by experienced personnel. For any procedure or field program, the time required for the first implementation by inexperienced personnel would be significantly higher.

7.2.1 Operational Implementation Costs for Tier 2 Screening Procedure

The Tier 2 screening procedure involves i) identification of sites with fine-grained soils at the water table and ii) application of an adjustment factor to Tier 1 screening criteria to account for higher VOC attenuation observed at such sites (see Section 6.4). Operational implementation costs are associated with the first step (determination of whether the site has fine-grained soils at the water table). As discussed in Sections 6.2 and 6.4, two methods were validated at the demonstration sites. The presence of fine-grained soils at the water table can be determined either by i) visual inspection of soil cores (or review of boring logs generated during the installation of borings or monitoring wells) or ii) field measurement of soil permeability. Estimated costs to implement these alternatives are summarized in Table 7.2.1, and are minimal because the screening can leverage existing data or be added to common field programs without causing significant disruption.

Table 7.2.1: Costs for Routine Implementation of Tier 2 Screening

Method 1: Visual Inspection of Cores or Logs		
Cost Element	**Labor Hours**	**Estimated Cost**
1. Visual inspection of cores during implementation of other field program or collection and review of existing boring logs	2	$ 200
2. Documentation of soil type observed within 2 ft of the water table	1	$ 100
Total Estimated Implementation Costs for Method 1		$ 300
Method 2: Field Measurement of Soil Permeability		
Cost Element	**Labor Hours**	**Estimated Cost**
1. Prepare for and conduct field test during implementation of other field program. Assumptions: i) test conducted at 3 locations; ii) test points already installed as part of other field program; and iii) test is conducted in conjunction with other field work (i.e., no additional mobilization time required).	6	$ 600
2. Analysis of field measurement; documentation of field methods and calculation methods.	4	$ 400
Total Estimated Implementation Costs for Method 2		$ 1000

Note: Labor costs of $100/hour were assumed.

7.2.2 Operational Implementation Costs for Tier 3 Investigation

The Tier 3 investigation procedure described in Section 6.5 involves manipulating building pressure and collecting air samples during 3 different pressure conditions: baseline, negative pressure, and positive pressure. Estimated costs to implement the Tier 3 procedure are shown in Table 7.2.2. The sampling itself takes place over the course of 3 days, with 4 to 6 hours per day for each of two persons assumed for equipment checks, setup and pickup.

Table 7.2.2: Costs for Routine Implementation of Tier 3 Procedure

Cost Element	Category				Unit Cost	Cost	Subtotal
1. Project planning and preparation[1]	Labor	Senior Project Scientist/Engineer	4	hours	$150/hr	$ 600	
	Labor	Project Scientist / Engineer	6	hours	$100/hr	$ 600	$ 1200
2. Pressure control and sampling field program	Labor	Senior Project Scientist/Engineer	16	hours	$150/hr	$ 2400	
	Labor	Project Scientist / Engineer	16	hours	$100/hr	$ 1600	
	Equipment Rental	Floor fan, differential pressure recorder	$225	per building	-	$ 225	
	Sample Analysis	VOCs (4 samples + 1 field duplicate)	5	samples	$270/spl	$ 1350	
	Sample Analysis	Radon (5 samples + 1 field duplicate)	6	samples	$110/spl	$ 660	$ 6235
3. Data evaluation and reporting[1]	Labor	Senior Project Scientist/Engineer	4	hours	$150/hr	$ 600	
	Labor	Project Scientist / Engineer	6	hours	$100/hr	$ 600	$ 1200
						Project Total:	$ 8635

Note: 1) Estimates for project planning (Task 1) and (Task 3) are the per-building cost assuming application of the procedure at four or more buildings during a single field program. The per-building costs would be larger if applied to only one to three buildings.
2) Cost estimates do not include travel to the site. The actual number of samples will depend on the building configuration.

7.3 COST DRIVERS

The cost for implementation of the Tier 2 screening procedure and Tier 3 investigation procedure is not expected to vary significantly based on specific site characteristics. The Tier 2 screening procedure can typically be implemented utilizing exiting site data without significant cost. The Tier 3 investigation procedure uses a fixed sampling program that will not vary based on site-specific characteristics.

8.0 IMPLEMENTATION ISSUES

8.1 COST-RELATED ISSUES

The cost for implementation of the Tier 2 screening procedure and Tier 3 investigation procedure is not expected to vary significantly based on specific site characteristics. Rather, the cost benefit of implementing these procedures in lieu of the current standard vapor intrusion pathway evaluation will depend primarily on local regulatory requirements.

8.1.1 Cost Drivers for Tier 2 Screening Procedure

The cost for implementation of the Tier 2 screening procedure is minimal when existing soil boring logs are used to determine the presence of fine-grained soils at the water table because the procedure does not require collection of any additional site data. At fine-grained soil sites where VOC concentrations in groundwater are greater than Tier 1 screening concentration but less than 100 times the Tier 1 screening concentrations, this procedure can be used to help justify no further evaluation of the vapor intrusion pathway, eliminating additional field investigation costs.

As discussed in Section 6.2, field measurement of soil permeability was a slightly more accurate method for identification of fine-grained soil sites with high VOC attenuation from groundwater to deep soil gas. However, measurement of soil permeability does require additional field measurements not routinely implemented during typical vapor intrusion pathway investigations. The decision regarding whether to conduct soil permeability measurements in support of the Tier 2 screening procedure will likely depend on the strength of other available lines of evidence to support the vapor intrusion pathway evaluation.

8.1.2 Cost Drivers for Tier 3 Investigation Procedure

The Tier 3 investigation procedure has been developed to provide a more definitive evaluation of vapor intrusion relative to the typical building-specific investigation program. The cost benefit of the Tier 3 procedure should be evaluated based on the expected cost for the typical vapor intrusion sampling program (Table 8.1.1).

Table 8.1.1: Estimated Cost of Typical Vapor Intrusion Investigation at One Building

Cost Element	Category				Unit Cost	Cost	Subtotal
1. Project planning and preparation[1]	Labor	Senior Project Scientist/Engineer	4	hours	$150/hr	$ 600	
	Labor	Project Scientist / Engineer	6	hours	$100/hr	$ 600	$ 1200
2. Standard sampling field program	Labor	Senior Project Scientist/Engineer	6	hours	$150/hr	$ 900	
	Labor	Project Scientist / Engineer	6	hours	$100/hr	$ 600	
	Equipment Rental, Supplies	Sub-slab point installation, leak tracer gas (e.g., helium), helium meter	$1000	per building	-	$ 1000	
	Sample Analysis	VOCs (7 samples + 1 field duplicate)	8	samples	$270/spl	$ 2160	
	Sample Analysis	Radon (6 samples + 1 field duplicate)	7	samples	$110/spl	$ 770	$ 5430
3. Data evaluation and reporting[1]	Labor	Senior Project Scientist/Engineer	4	hours	$150/hr	$ 600	$ 1200
	Labor	Project Scientist / Engineer	6	hours	$100/hr	$ 600	
						Project Total:	$ 7830

Note: Cost estimates do not include travel to the site. Assumptions include installation of sub-slab sample points, leak testing, and collection of 3 sub-slab, 3 indoor air, and 1 ambient air samples and field duplicates. Labor hours assume 4 hours for building inspection and 8 hours for sub-slab sample point installations, sample setup, collection, and pickup.

For a single round of investigation, the cost of the Tier 3 procedure is higher than a standard vapor intrusion investigation (i.e., $8,600/building vs. $7,800/building, assuming multiple buildings are being testing in one field mobilization). However, regardless of the results obtained from the initial standard investigation, additional rounds of sampling are likely to be required. If the initial sampling indicates VOC concentrations in indoor air below screening values, one to three additional rounds of sampling may be required to characterize temporal variability. For example, the Montana DEQ requires a minimum of two rounds of sampling. For a site in Iowa, the USEPA project manager recently requested four rounds of sampling to characterize temporal variability. Also, the forthcoming revision of the USEPA Vapor Intrusion Guidance is likely to recommend multiple rounds of sampling for most sites. If VOC concentrations in indoor air are above screening values, follow-up sampling is commonly required to determine the impact of indoor sources.

As discussed in Section 6.3, the Tier 3 procedure reduces the need to characterize temporal variability by ensuring conditions conducive to vapor intrusion during a single sampling event. In addition, the results from the Tier 3 procedure provide an improved understanding of the contribution of indoor sources. As a result, for many sites, the Tier 3 procedure is more likely to provide a definitive evaluation of vapor intrusion than a single round of typical sampling. A single round of sampling using the Tier 3 procedure is 45% less expensive than two rounds of standard sampling and 72% less expensive than four rounds of standard sampling.

8.2 OTHER CONSIDERATONS

This project has resulted in development of Tier 2 screening procedures and Tier 3 investigation procedures that provide additional tools to assist in vapor intrusion investigations. Limitations to use of these tools include:

- The **Tier 2** screening procedures will be useful only at certain sites (i.e., sites with fine-grained soil layers within two ft above the water table. Sites with exclusively sandy soils and sites in dry climates with low moisture content soils will not benefit). Additionally, the Tier 2 screening procedure should not be applied to sites where the depth to groundwater is less than 5 ft bgs. Also, the Tier 2 adjustment factor should only be applied to generic Tier 1 screening values which do not take soil type into consideration.

  Note that, although the demonstration dataset support use of 100x as a conservative adjustment factor under the stated conditions, final regulatory acceptance of this adjustment factor is likely to be based on a combination of technical and policy considerations including the overall level of conservatism required for evaluation of the vapor intrusion pathway.

- The **Tier 3** procedure is not applicable to very large or very leaky buildings where the building pressure cannot be easily controlled. In addition, the pressure control method does not eliminate the spatial variability in VOC concentrations that is observed at many investigation sites. Results showing that vapor intrusion occurs only under depressurized conditions will not be directly applicable to normal building operating conditions because the observed magnitude of vapor intrusion under these conditions may be greater than under normal operating conditions. In these cases, the investigator may choose either preemptive mitigation or continued monitoring.

9.0 REFERENCES

Connor, J.A., and T.E. McHugh, "Impact of Risk-Based Corrective Action (RBCA) on State Corrective Action Programs", Human and Ecological Risk Assessment, CRC Press, Volume 8, Number 2, April 2002.

DiGiulio, D., C. Paul, et al. *Assessment of Vapor Intrusion in Homes Near the Raymark Superfund Site Using Basement and Sub-Slab Air Samples*. March 2006. U.S. EPA Office of Research and Development. Publication Number EPA/600/R-05/147.

Eklund B.M., Simon, M.A. Concentration of tetrachloroethylene in indoor air at a former dry cleaner facility as a function of subsurface contamination: a case study. J Air Waste Manag Assoc. 2007 Jun;57(6):753-60.

Folkes, D., Wertz, W., Kurtz, J., Kuehster, T., 2009. Observed Spatial and Temporal Distributions of cVOCs at Colorado and New York Vapor Intrusion Sites. GWMR. V. 29, No. 1, pp. 70-80.

GSI Environmental, 2008. ER-0707 Project Report: Proposed Tier 2 Screening Criteria and Tier 3 Field Procedures for Evaluation of Vapor Intrusion, Issued February 1, 2008.

Interstate Technology & Regulatory Council (ITRC), 2007. Vapor Intrusion: A Practical Guideline. Interstate Technology & Regulatory Council, Washington, DC, Copyright 2007.

McHugh T.E., Hammond, D.E., Nickels, T., Hartman, B. *Use of Radon Measurements for Evaluation of VOC Vapor Intrusion*. Environmental Forensics, Vol. 9 No. 1, March 2008

New Jersey Department of Environmental Protection (NJDEP). *Vapor Intrusion Guidance*. 2006. Available at http://www.nj.gov/dep/srp/guidance/vaporintrusion/vig.htm

New York Department of Health (NYDOH). *Guidance for Evaluating Soil Vapor Intrusion in the State of New York*. 2006. Available at http://www.health.state.ny.us/environmental/investigations/soil_gas/svi_guidance/

Sanders, P.F., and Hers, I., 2006. Vapor Intrusion in Homes over Gasoline-Contaminated Ground Water in Stafford, New Jersey, Ground Water Monitoring & Remediation V. 26, No. 1, Winter 2006, pp. 63-72.

Schuver, H. *Background of the Vapor Intrusion Pathway & Status of USEPA's Guidance.* 2005. STL Technical Guidance for Indoor Air Vapor Intrusion, Alamo, CA.

Tillman, F. D. and J. W. Weaver. *Review of Recent Research on Vapor Intrusion*, U.S. EPA Office of Research and Development. 2005. Publication Number EPA/600/R-05/106.

USEPA. *Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (Subsurface Vapor Intrusion Guidance).* 2002. Available at http://www.epa.gov/epaoswer/hazwaste/ca/eis/vapor.htm.

USEPA, 2010. Review of the Draft 2002 Subsurface Vapor Intrusion Guidance, Office of Solid Waste and Emergency Response. August 2010. Available at http://www.epa.gov/oswer/vaporintrusion/.

USGS, 2006. Description, Properties, and Degradation of Selected Volatile Organic Compounds Detected in Ground Water – A Review of Selected Literature, U.S. Geological Survey Open-File Report 2006-1338.

Environmental Security Technology Certification Program
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FINAL REPORT

Proposed Tier 2 Screening Criteria and Tier 3 Field Procedures for Evaluation of Vapor Intrusion
ESTCP Project ER-200707

APPENDICES

Environmental Security Technology Certification Program
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Appendix A: Results from Individual Demonstration Sites

Appendix A.1	**Former Pioneer Dry Cleaners, Houston, Texas**
Appendix A.2	**Travis Air Force Base, Fairfield, California**
Appendix A.3	**Jacksonville Naval Air Station, Jacksonville, Florida**
Appendix A.4	**Parris Island Marine Base, South Carolina**
Appendix A.5	**Tinker Air Force Base, Oklahoma City, Oklahoma**
Appendix A.6	**Hill Air Force Base, Layton, Utah**
Appendix A.7	**Moffett Field Naval Air Station, Moffett Field, California**
Appendix A.8	**SPAWAR OTC Facility, San Diego, California**
Appendix A.9	**NIKE Battery Site PR-58, N. Kingstown, Rhode Island**
Appendix A.10	**Industrial Site, Southeast Texas**

Environmental Security Technology Certification Program
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FINAL REPORT

Proposed Tier 2 Screening Criteria and Tier 3 Field Procedures for Evaluation of Vapor Intrusion
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Appendix A.1: Former Pioneer Dry Cleaners, Houston, Texas

TABLES

FIGURES

TABLE A.1.1
RESULTS OF GEOTECHNICAL ANALYSES
ESTCP Tier 2 Vapor Screening Study
Former Pioneer Dry Cleaners, Homestead Shopping Plaza, Houston, Texas

Sample ID	Sample Depth	Dry Bulk Density	Fraction Organic Carbon	Volumetric Water Content	Porosity		Intrinsic Permeability to Water	Native Hydraulic Conductivity
					Total	Air Filled	5 PSI Confining Stress	
Units	ft	pcf	%	--	--	--	cm^2	cm/sec
C1-PZ-2	3-4	108.7	1.9	0.283	0.349	0.066	9.6E-13	9.4E-08
C1-PZ-2	8-9	114.1	1.8	0.295	0.311	0.016	2.4E-13	2.3E-08
C1-PZ-2	11-12	106.5	1.4	0.346	0.361	0.015	5.8E-13	5.7E-08
C1-PZ-2	15.5-16.5	114.5	4.4	0.288	0.325	0.037	3.4E-14	3.3E-09
C2-PZ-2	3-4	115.9	2.6	0.266	0.307	0.041	1.3E-13	1.3E-08
C2-PZ-2	7-8	114.9	3.4	0.311	0.315	0.005	6.1E-14	6.0E-09
C2-PZ-2	12-13	114.6	1.5	0.301	0.310	0.009	4.3E-13	4.2E-08
C2-PZ-2	16-17	114.9	2.3	0.276	0.317	0.042	2.9E-11	2.8E-06
C3-PZ-2	2.75-3.75	105.9	1.7	0.341	0.365	0.024	1.3E-14	1.3E-09
C3-PZ-2	7-8	105.4	3.1	0.358	0.368	0.020	1.9E-14	1.8E-09
C3-PZ-2	11-12	113.4	1.5	0.282	0.323	0.041	1.9E-12	1.8E-07
C3-PZ-2	16-17	115.5	3.4	0.243	0.312	0.069	1.9E-14	1.8E-09
C3-PZ-2	20-21	116.8	2.7	0.287	0.309	0.022	7.1E-15	6.9E-10

Notes:
1. Samples were analyzed by Fugro Consultants, Inc. in Houston, Texas.
2. Dry bulk density determined by D 2166, Fraction Organic Carbon determined by D 2974, intrinsic permeability and hydraulic conductivity determined by D 5084, volumetric moisture content determined by D 2435, and total and air-filled porosity determined by D 653.
3. All sample orientations were vertical.

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TABLE A.1.2
SAMPLING POINT COMPLETION DETAILS: CLUSTERS
ESTCP Tier 2 Vapor Screening Study
Former Pioneer Dry Cleaners, Homestead Shopping Plaza, Houston, Texas

Well ID	Installed Total Depth (ft, bgs)	Screen Interval Depth (ft, bgs)	Screen Slot Size (--)	Boring Hole Diameter (inches)	Well Diameter (inches)	Sand Backfill Filter Pack		Tubing Diameter (inches)
						U.S. Mesh Interval	Filter Pack Thickness (ft)	
Cluster 1								
C1-PZ-1	30.0	29.5 - 30	No. 010	2.25	1	20/40	2.5	N/A
C1-PZ-2	22.0	21.5 - 22	No. 010	2.25	1	20/40	2.5	N/A
C1-PZ-3	13.0	12.5 - 13	No. 010	2.25	1	20/40	2.5	N/A
C1-PZ-4	11.5	11 - 11.5	No. 010	2.25	1	20/40	2.5	N/A
C1-PZ-5	10.0	9.5 - 10	No. 010	2.25	1	20/40	2.5	N/A
C1-SG-1	11.5	N/A	N/A	2.25	N/A	20/40	1	1/8
C1-SG-2	10.0	N/A	N/A	2.25	N/A	20/40	1	1/8
C1-SG-3	8.0	N/A	N/A	2.25	N/A	20/40	1	1/8
C1-SG-4	5.0	N/A	N/A	2.25	N/A	20/40	1	1/8
C1-SG-5	2.0	N/A	N/A	2.25	N/A	20/40	1	1/8
Cluster 2								
C2-PZ-1	28.0	27.5 - 28	No. 010	2.25	1	20/40	2.5	N/A
C2-PZ-2	20.0	19.5 - 20	No. 010	2.25	1	20/40	2.5	N/A
C2-PZ-3	12.5	12 - 12.5	No. 010	2.25	1	20/40	2.5	N/A
C2-PZ-4	10.5	10 - 10.5	No. 010	2.25	1	20/40	2.5	N/A
C2-PZ-5	8.5	8 - 8.5	No. 010	2.25	1	20/40	2.5	N/A
C2-SG-1	10.5	N/A	N/A	2.25	N/A	20/40	1	1/8
C2-SG-2	8.5	N/A	N/A	2.25	N/A	20/40	1	1/8
C2-SG-3	6.5	N/A	N/A	2.25	N/A	20/40	1	1/8
C2-SG-4	4.5	N/A	N/A	2.25	N/A	20/40	1	1/8
C2-SG-5	2.0	N/A	N/A	2.25	N/A	20/40	1	1/8
Cluster 3								
C3-PZ-1	30.5	30 - 30.5	No. 010	2.25	1	20/40	2.5	N/A
C3-PZ-2	21.5	21 - 21.5	No. 010	2.25	1	20/40	2.5	N/A
C3-PZ-3	12.5	12 - 12.5	No. 010	2.25	1	20/40	2.5	N/A
C3-PZ-4	10.0	9.5 - 10	No. 010	2.25	1	20/40	2.5	N/A
C3-PZ-5	8.0	7.5 - 8	No. 010	2.25	1	20/40	2.5	N/A
C3-SG-1	10.0	N/A	N/A	2.25	N/A	20/40	1	1/8
C3-SG-2	8.0	N/A	N/A	2.25	N/A	20/40	1	1/8
C3-SG-3	6.0	N/A	N/A	2.25	N/A	20/40	1	1/8
C3-SG-4	4.0	N/A	N/A	2.25	N/A	20/40	1	1/8
C3-SG-5	2.0	N/A	N/A	2.25	N/A	20/40	1	1/8

Notes:
1. Well locations are shown on Figure A.1.1.
2. All locations were completed to the surface with a bentonite seal.
3. bgs = Below ground surface.

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TABLE A.1.3
DEPTH TO WATER MEASUREMENTS
ESTCP Tier 2 Vapor Screening Study
Former Pioneer Dry Cleaners, Homestead Shopping Plaza, Houston, Texas

Well ID	Installed Total Depth (ft, bgs)	Screen Interval Depth (ft, bgs)	12/22/2008 Depth to Water (ft, bgs)	1/5/2009 Depth to Water (ft, bgs)	1/9/2009 Depth to Water (ft, bgs)	1/9/2009 Measured Total Depth (ft, bgs)
Cluster 1						
C1-PZ-1	30.0	29.5 - 30	11.20	11.16	11.15	28.4
C1-PZ-2	22.0	21.5 - 22	12.08	9.88	9.55	21.2
C1-PZ-3	13.0	12.5 - 13	10.39	9.83	9.51	12.7
C1-PZ-4	11.5	11 - 11.5	DRY	10.40	9.17	11.2
C1-PZ-5	10.0	9.5 - 10	DRY	DRY	DRY	9.6
Cluster 2						
C2-PZ-1	28.0	27.5 - 28	8.51	8.27	8.42	27.9
C2-PZ-2	20.0	19.5 - 20	6.20	6.15	5.81	19.3
C2-PZ-3	12.5	12 - 12.5	9.26	6.06	5.88	12.1
C2-PZ-4	10.5	10 - 10.5	9.18	5.86	5.87	10.1
C2-PZ-5	8.5	8 - 8.5	DRY	5.70	5.70	8.1
Cluster 3						
C3-PZ-1	30.5	30 - 30.5	9.67	9.94	9.95	29.4
C3-PZ-2	21.5	21 - 21.5	DRY	20.84	20.45	21.2
C3-PZ-3	12.5	12 - 12.5	DRY	DRY	DRY	12.0
C3-PZ-4	10.0	9.5 - 10	DRY	DRY	DRY	9.8
C3-PZ-5	8.0	7.5 - 8	DRY	5.96	5.90	7.5

Notes:
1. Well locations are shown on Figure A.1.1.
2. bgs = Below ground surface.

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TABLE A.1.4
RESULTS OF GROUNDWATER ANALYSES: COMPOUNDS OF INTEREST
ESTCP Tier 2 Vapor Screening Study
Former Pioneer Dry Cleaners, Homestead Shopping Plaza, Houston, Texas

		DUPLICATE					*DUPLICATE*	
SAMPLE LOCATION:	C1-PZ-1	C1-PZ-1	C1-PZ-2	C1-PZ-3	C1-PZ-4	C2-PZ-1	C2-PZ-1	C2-PZ-2
SCREEN INTERVAL (FT, BGS):	29.5-30	29.5-30	21.5-22	12.5-13	11-11.5	27.5-28	27.5-28	19.5-20
SAMPLE DATE:	1/9/2009	1/9/2009	1/9/2009	1/9/2009	1/9/2009	1/9/2009	1/9/2009	1/9/2009
COMPOUND	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Volatile Organic Compounds (VOCs) by Method 8260B								
Dichloroethene, cis-1,2-	**0.97**	**1**	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Dichloroethene, trans-1,2-	**0.014**	**0.014**	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Tetrachloroethene	**15**	**17**	<0.005	**0.006**	<0.005	<0.005	<0.005	<0.005
Trichloroethene	**0.93**	**1**	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Vinyl chloride	**0.043**	**0.041**	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

SAMPLE LOCATION:	C2-PZ-3	C2-PZ-4	C2-PZ-5	C3-PZ-1	C3-PZ-2	C3-PZ-5	Field Blank	Trip Blank
SCREEN INTERVAL (FT, BGS):	12-12.5	10-10.5	8-8.5	30-30.5	21-21.5	7.5-8	NA	NA
SAMPLE DATE:	1/9/2009	1/9/2009	1/9/2009	1/9/2009	1/9/2009	1/9/2009	1/9/2009	NA
COMPOUND	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Volatile Organic Compounds (VOCs) by Method 8260B								
Dichloroethene, cis-1,2-	<0.005	<0.005	<0.005	**0.2**	<0.005	<0.005	<0.005	<0.005
Dichloroethene, trans-1,2-	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Tetrachloroethene	<0.005	<0.005	<0.005	**0.1**	<0.005	<0.005	<0.005	<0.005
Trichloroethene	<0.005	<0.005	<0.005	**0.034**	<0.005	<0.005	<0.005	<0.005
Vinyl chloride	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Notes:
1. Sampling locations are shown on Figure A.1.1.
2. Samples were analyzed by Southern Petroleum Laboratories in Houston, Texas by Method 8260B.
3. Detected analytes are presented in **bold** type.
4. < = Not detected at detection limit shown.

GSI ENVIRONMENTAL

TABLE A.1.5
RESULTS OF SOIL GAS ANALYSES: COMPOUNDS OF INTEREST
ESTCP Tier 2 Vapor Screening Study
Former Pioneer Dry Cleaners, Homestead Shopping Plaza, Houston, Texas

		DUPLICATE				
SAMPLE LOCATION:	C1-SG-2	C1-SG-2	C1-SG-3	C1-SG-4	C1-SG-5	C2-SG-4
SCREEN INTERVAL (FT, BGS):	11-11.5	11-11.5	7.5-8	4.5-5	1.5-2	4-4.5
SAMPLE DATE:	1/9/2009	1/9/2009	1/9/2009	1/9/2009	1/9/2009	1/9/2009
SAMPLE COLLECTION METHOD:	Syringe/Tedlar	Syringe/Tedlar	Syringe/Tedlar	Syringe/Tedlar	Syringe/Tedlar	Syringe/Tedlar
COMPOUND	ug/m^3	ug/m^3	ug/m^3	ug/m^3	ug/m^3	ug/m^3
Volatile Organic Compounds (VOCs) by Method TO-15						
Dichloroethene, cis-1,2-	<79	<40	<40	<5.2	<40	<12
Dichloroethene, trans-1,2-	<79	<40	<40	<5.2	<40	<12
Tetrachloroethene	<140	<68	<68	<8.8	<68	<20
Trichloroethene	<110	<54	<54	<7	<54	<16
Vinyl Chloride	<51	<26	<26	<3.3	<26	<7.7

SAMPLE LOCATION:	C2-SG-5	C3-SG-1	C3-SG-2	C3-SG-4
SCREEN INTERVAL (FT, BGS):	1.5-2	9.5-10	7.5-8	3.5-4
SAMPLE DATE:	1/9/2009	1/9/2009	1/9/2009	1/9/2009
SAMPLE COLLECTION METHOD:	Syringe/Tedlar	Syringe/Tedlar	Syringe/Tedlar	Syringe/Tedlar
COMPOUND	ug/m^3	ug/m^3	ug/m^3	ug/m^3
Volatile Organic Compounds (VOCs) by Method TO-15				
Dichloroethene, cis-1,2-	<16	<99	<40	<20
Dichloroethene, trans-1,2-	<16	<99	<40	<20
Tetrachloroethene	<27	<170	<68	<34
Trichloroethene	<21	<130	<54	<27
Vinyl Chloride	<10	<64	<26	<13

Notes:
1. Sampling locations are shown on Figure A.1.1.
2. Samples were analyzed by Southern Petroleum Laboratories in Houston, Texas by Method TO-15.
3. Detected analytes are presented in **bold** type.
4. < = Not detected at detection limit shown; E = Estimated values; exceeds calibration curve.
5. NM = Not measured.

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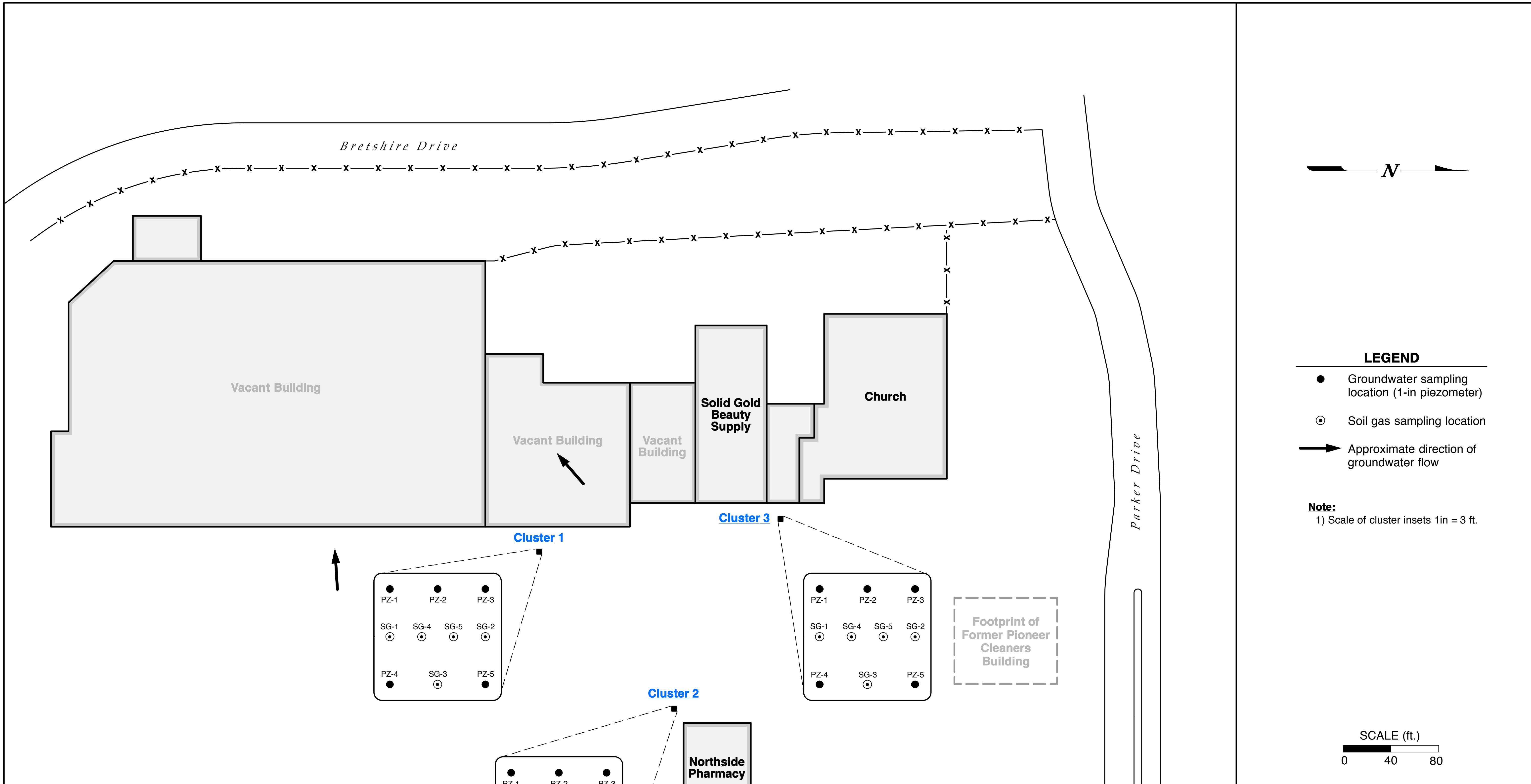
TABLE A.1.6
RESULTS OF SOIL PERMEABILITY TESTING
ESTCP Tier 2 Vapor Screening Study
Former Pioneer Dry Cleaners, Homestead Shopping Plaza, Houston, Texas

Cluster Location	Sample Point	Air Flow Rate (Q)		Vacuum (P)		Slope of Q vs. P	Permeability (cm2)
		(L/min)	(cc/min)	(in. Hg)	(in. H2O)		
Cluster 1	PZ-5	2.2	2200	12.0	163	11	3.12E-10
		1.1	1100	6.0	81.6		
		0.5	500	2.0	27.2		
		0.38	380	1.1	15.5		
		0.15	150	0.7	9.5		
		0.37	370	1.1	14.5		
		1.1	1100	2.5	34		
		2.8	2800	17.0	231		
Cluster 2	PZ-4	2	1600	24.0	326	4.51	1.24E-10
		1	1200	18.0	245		
		0	320	3.2	44		
		0	160	1.6	22		
		0	460	4.3	58		
		1.6	1600	24.0	326		
Cluster 3	PZ-3	1.3	1300	26.0	354	3.1	8.41E-11
		0.19	190	22.0	299		
		0.14	140	8.5	116		
		0.08	80	4.4	60		

Parameter	Symbol	Value	Units	Basis
Viscosity of air	viscosity	1.73E-04	g/cm-s (poise)	Literature (40 deg. F)
Length: Mont. Well	L	15.2	cm	Screen length for monitoring well points (6 inches)
Diameter: Mont. Well	D	3.2	cm	Inside diameter for monitoring well points
Units Conversion		1.07E-06		From calculation methods sheet
L/D Term: Well Pt		0.1486		Calculated

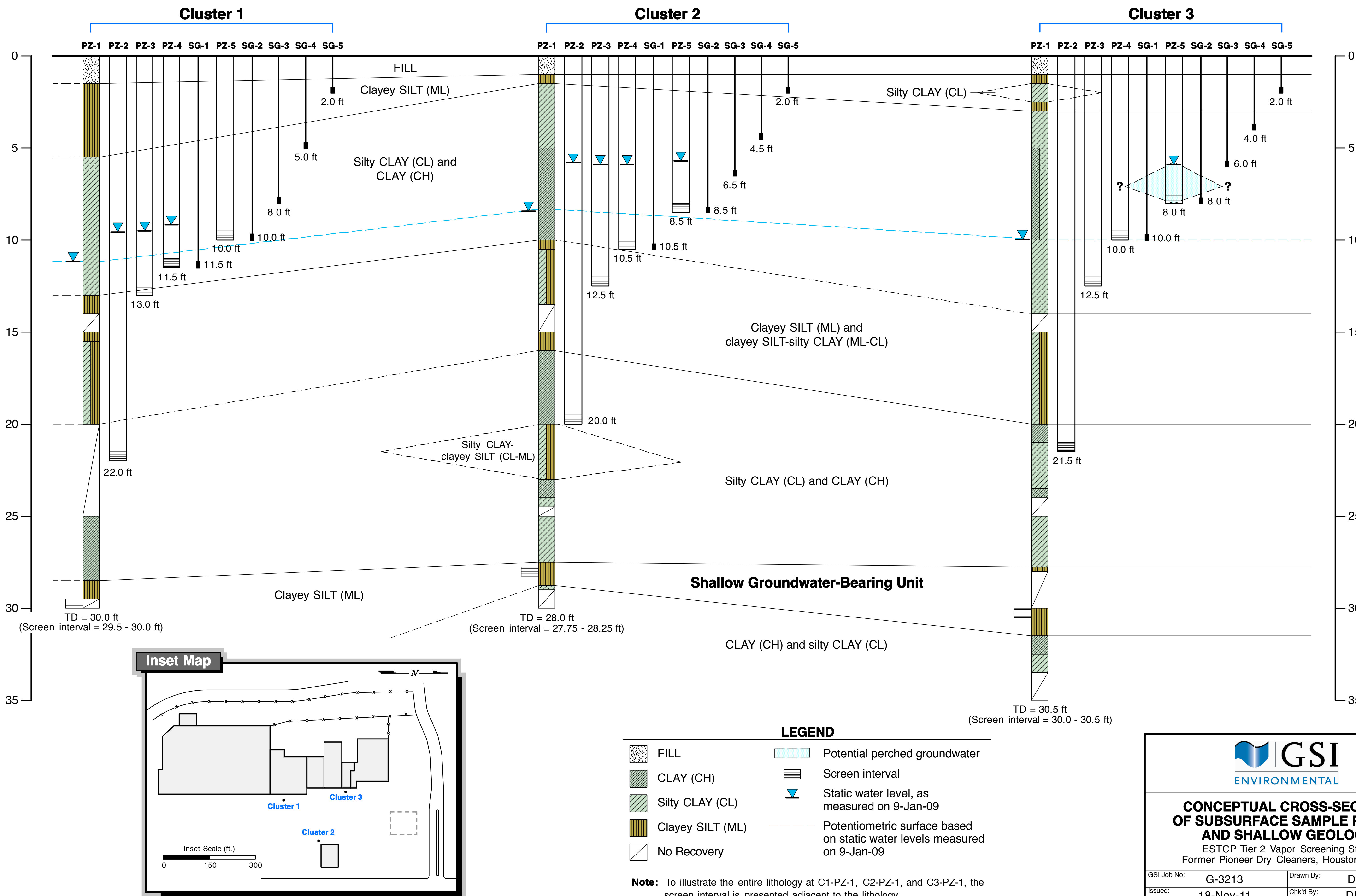


GSI ENVIRONMENTAL

GROUNDWATER AND SOIL GAS SAMPLING LOCATIONS

ESTCP Tier 2 Vapor Screening Study
Former Pioneer Dry Cleaners, Houston, Texas

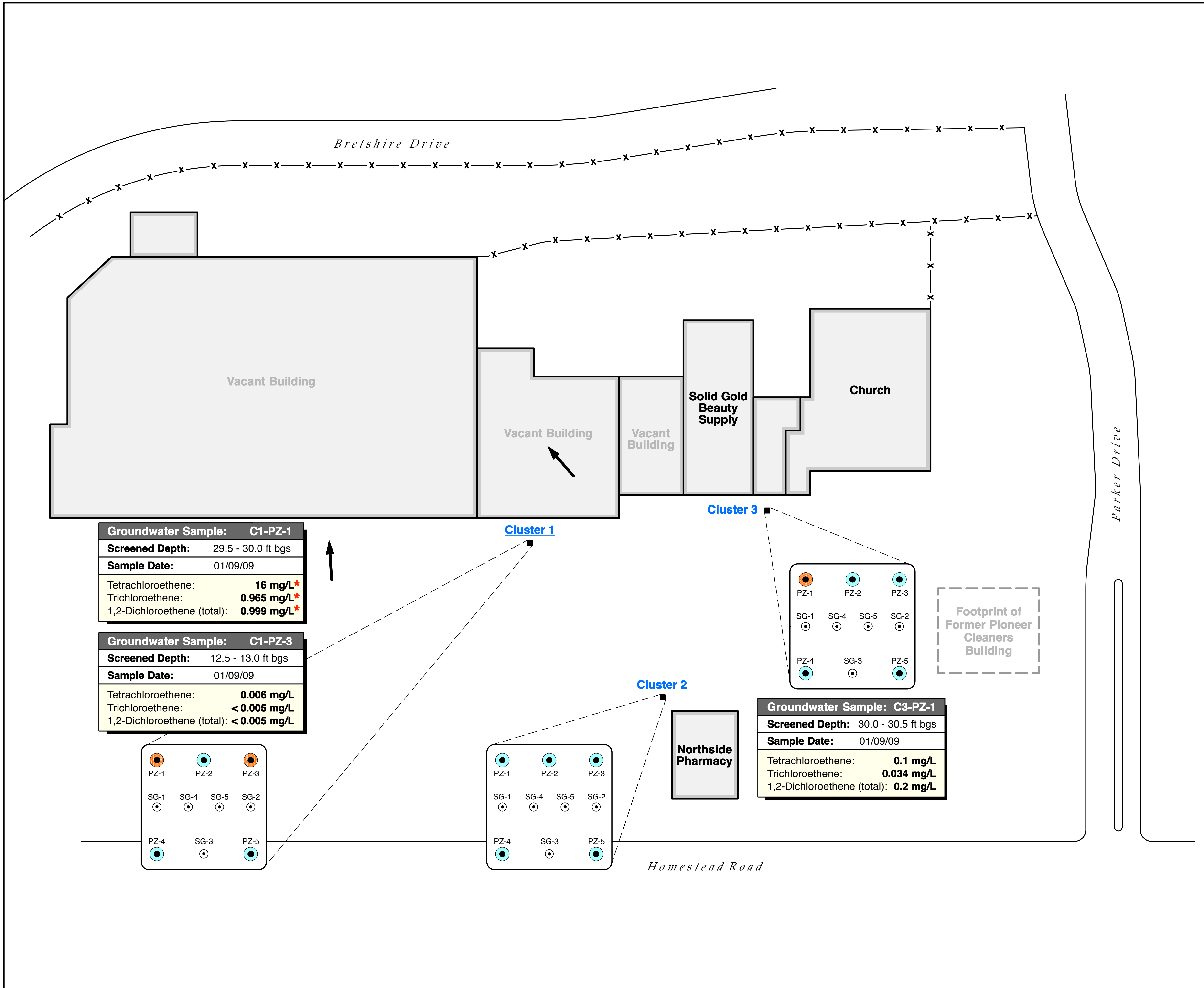
GSI Job No: G-3213		Drawn By:	DLB
Issued: 18-Nov-11		Chk'd By:	RCL
Revised: ——		Appv'd By:	LMB
Scale: As Shown		**FIGURE A.1.1**	



CONCEPTUAL CROSS-SECTION OF SUBSURFACE SAMPLE POINTS AND SHALLOW GEOLOGY

ESTCP Tier 2 Vapor Screening Study
Former Pioneer Dry Cleaners, Houston, Texas

GSI Job No: G-3213		Drawn By: DLB	
Issued: 18-Nov-11		Chk'd By: DMB	
Revised: ———		Appv'd By: LMB	
Scale: As Shown		**FIGURE A.1.2**	



N

LEGEND

- Groundwater sampling location (1-in piezometer)
- Soil gas sampling location
- One or more COCs detected above the reporting limit
- COCs not detected
- * Duplicate samples taken; average value shown
- Approximate direction of groundwater flow
- —x—x— Fenceline

Notes:

1) COC = Constituent of Concern (i.e., PCE, TCE, and 1,2-DCE)
2) Groundwater samples were analyzed by Southern Petroleum Laboratories in Houston, Texas.
3) PCE = Tetrachloroethene
TCE = Trichloroethene
1,2-DCE = 1,2-Dichloroethene
bgs = Below ground surface
4) Scale of cluster insets 1in = 3 ft.

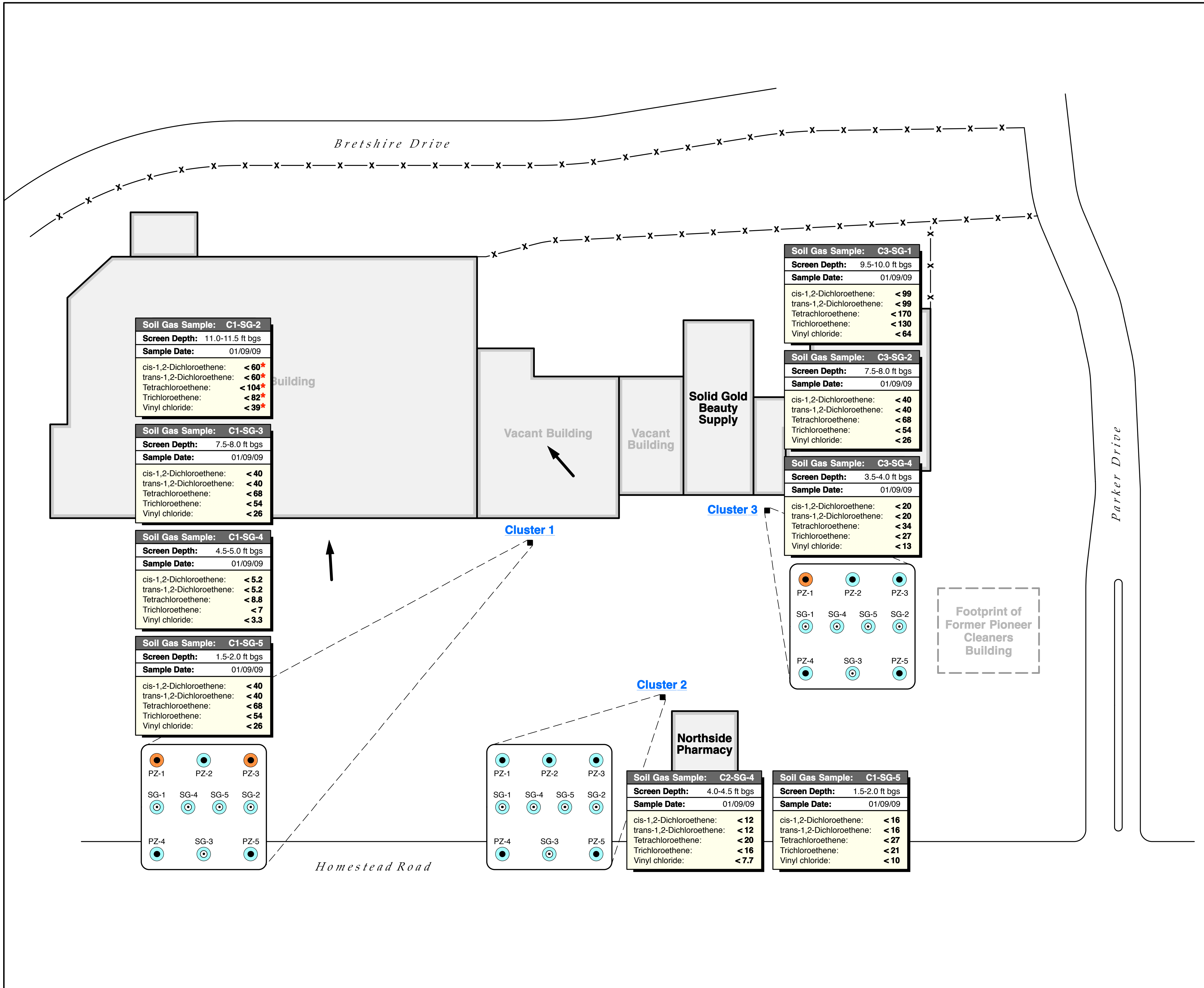
SCALE (ft.)
0 40 80

GSI ENVIRONMENTAL

GROUNDWATER SAMPLING AND TESTING RESULTS

ESTCP Tier 2 Vapor Screening Study
Former Pioneer Dry Cleaners, Houston, Texas

GSI Job No: G-3213		Drawn By: DLB	
Issued: 18-Nov-11		Chk'd By: RCL	
Revised: ———		Appv'd By: LMB	
Scale: As Shown		FIGURE A.1.3	



N

LEGEND

- Groundwater sampling location (1-in piezometer)
- Soil gas sampling location
- One or more COCs detected above the reporting limit
- COCs not detected
- * Duplicate samples taken; average value shown
- Approximate direction of groundwater flow
- —x—x— Fenceline

Notes:

1) COC = Constituent of Concern (i.e., PCE, TCE, and 1,2-DCE)
2) No COCs detected in all soil gas samples.
3) Soil gas samples were analyzed by Southern Petroleum Laboratories in Houston, Texas.
4) PCE = Tetrachloroethene
TCE = Trichloroethene
1,2-DCE = 1,2-Dichloroethene
bgs = Below ground surface
5) Scale of cluster insets 1in = 3 ft.

SCALE (ft.)
0 40 80

GSI ENVIRONMENTAL

SOIL GAS SAMPLING AND TESTING RESULTS

ESTCP Tier 2 Vapor Screening Study
Former Pioneer Dry Cleaners, Houston, Texas

GSI Job No:	G-3213	Drawn By:	DLB
Issued:	18-Nov-11	Chk'd By:	RCL
Revised:	———	Appv'd By:	LMB
Scale:	As Shown		FIGURE A.1.4

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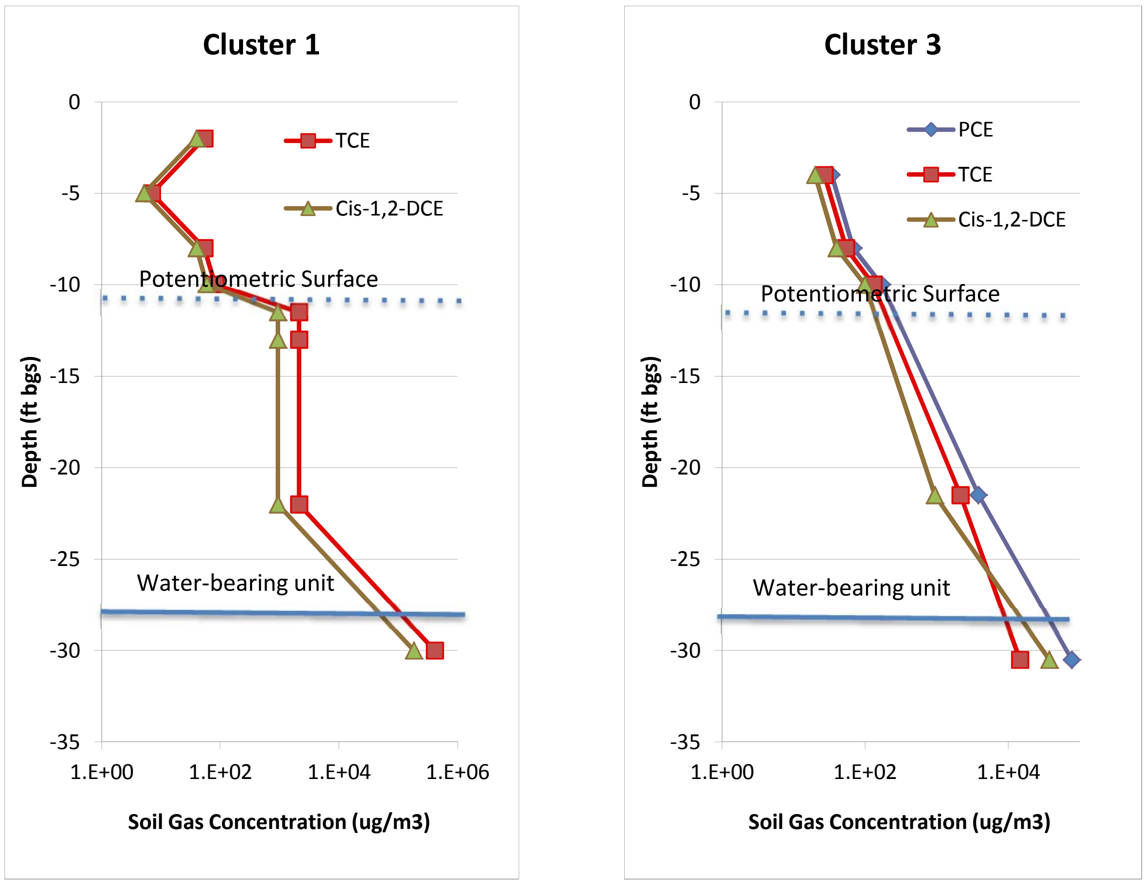
FIGURE A.1.5
VERTICAL VOC PROFILE
ESTCP Tier 2 Vapor Screening Study
Former Pioneer Cleaners Site, Houston, Texas



* = Concentrations in groundwater (i.e., below the water table) were converted into equivalent soil gas concentrations using Henry's Law assuming equilibrium partitioning.
Note: No COCs detected at Cluster 2

Environmental Security Technology Certification Program
(ESTCP)

FINAL REPORT

Proposed Tier 2 Screening Criteria and Tier 3 Field Procedures for Evaluation of Vapor Intrusion
ESTCP Project ER-200707

Appendix A.2: Travis Air Force Base, Fairfield, California

TABLES

FIGURES

TABLE A.2.1
RESULTS OF GEOTECHNICAL ANALYSES
ESTCP Tier 2 Vapor Screening Study
Building 828, Travis Air Force Base, California

Sample ID	Sample Depth	Dry Bulk Density	Fraction Organic Carbon	Volumetric Water Content	Porosity		Intrinsic Permeability to Water	Native Hydraulic Conductivity
					Total	Air Filled	5 PSI Confining Stress	
Units	**ft**	**pcf**	**%**	**--**	**--**	**--**	**cm^2**	**cm/sec**
C1-PZ-2	2-3	110.77	4.3	0.304	0.343	0.041	8.5E-14	8.3E-09
C1-PZ-2	5-6	110.85	4.1	0.241	0.346	0.105	2.5E-12	2.4E-07
C1-PZ-2	12-13	99.91	5.0	0.333	0.412	0.080	9.9E-14	9.7E-09
C2-PZ-2	5-6	110.45	5.7	0.264	0.337	0.074	1.8E-14	1.8E-09
C2-PZ-2	10-11	115.75	2.0	0.274	0.300	0.026	5.8E-14	5.7E-09
C2-PZ-2	14-15	102.24	5.3	0.339	0.394	0.054	2.7E-13	2.6E-08
C3-PZ-2	1-2	101.16	5.5	0.255	0.382	0.127	4.7E-12	4.6E-07
C3-PZ-2	4-5	109.16	4.1	0.303	0.355	0.052	5.8E-14	5.7E-09
C3-PZ-2	8-9	112.85	5.0	0.257	0.326	0.069	1.4E-13	1.3E-08
C3-PZ-2	10.5-11.5	110.55	3.4	0.314	0.342	0.028	4.7E-14	4.6E-09
C3-PZ-2	14-15	103.04	5.4	0.388	0.399	0.011	1.4E-13	1.3E-08

Notes:
1. Samples were analyzed by Fugro Consultants, Inc. in Houston, Texas
2. Dry bulk density determined by D 2166, Fraction Organic Carbon determined by D 2974, intrinsic permeability and hydraulic conductivi determined by D 5084, volumetric moisture content determined by D 2435, and total and air-filled porosity determined by D 65
3. All sample orientations were vertical.

GSI ENVIRONMENTAL

TABLE A.2.2
SAMPLING POINT COMPLETION DETAILS: CLUSTERS
ESTCP Tier 2 Vapor Screening Study
Building 828, Travis Air Force Base, California

Well ID	Installed Total Depth (ft, bgs)	Screen Interval Depth (ft, bgs)	Screen Slot Size (--)	Boring Hole Diameter (inches)	Well Diameter (inches)	Sand Backfill Filter Pack		Tubing Diameter (inches)
						U.S. Mesh Interval	Filter Pack Thickness (ft)	
Cluster 1								
Groundwater Sampling Points								
C1-PZ-1	16.5	16-16.5	No. 010	2.25	1	20/40	2.5	N/A
C1-PZ-2	14.5	14-14.5	No. 010	2.25	1	20/40	2.5	N/A
C1-PZ-3	11.5	11-11.5	No. 010	2.25	1	20/40	2.5	N/A
C1-PZ-4	10.5	10-10.5	No. 010	2.25	1	20/40	2.5	N/A
C1-PZ-5	8.5	8-8.5	No. 010	2.25	1	20/40	2.5	N/A
Soil Gas Sampling Points								
C1-SG-1	10.5	N/A	N/A	2.25	N/A	20/40	1	1/8
C1-SG-2	8.5	N/A	N/A	2.25	N/A	20/40	1	1/8
C1-SG-3	6.5	N/A	N/A	2.25	N/A	20/40	1	1/8
C1-SG-4	4.5	N/A	N/A	2.25	N/A	20/40	1	1/8
C1-SG-5	2.5	N/A	N/A	2.25	N/A	20/40	1	1/8
Cluster 2								
Groundwater Sampling Points								
C2-PZ-1	16.5	16-16.5	No. 010	2.25	1	20/40	2.5	N/A
C2-PZ-2	13.0	12.5-13	No. 010	2.25	1	20/40	2.5	N/A
C2-PZ-3	10.0	9.5-10	No. 010	2.25	1	20/40	2.5	N/A
C2-PZ-4	9.0	8.5-9	No. 010	2.25	1	20/40	2.5	N/A
C2-PZ-5	7.5	7-7.5	No. 010	2.25	1	20/40	2.5	N/A
Soil Gas Sampling Points								
C2-SG-1	9.0	N/A	N/A	2.25	N/A	20/40	1	1/8
C2-SG-2	7.5	N/A	N/A	2.25	N/A	20/40	1	1/8
C2-SG-3	5.5	N/A	N/A	2.25	N/A	20/40	1	1/8
C2-SG-4	3.5	N/A	N/A	2.25	N/A	20/40	1	1/8
C2-SG-5	2.0	N/A	N/A	2.25	N/A	20/40	1	1/8

Continued on next page

GSI ENVIRONMENTAL

TABLE A.2.2 (CONTINUED)

SAMPLING POINT COMPLETION DETAILS: CLUSTERS

ESTCP Tier 2 Vapor Screening Study

Building 828, Travis Air Force Base, California

Well ID	Installed Total Depth (ft, bgs)	Screen Interval Depth (ft, bgs)	Screen Slot Size (--)	Boring Hole Diameter (inches)	Well Diameter (inches)	Sand Backfill Filter Pack		Tubing Diameter (inches)
						U.S. Mesh Interval	Filter Pack Thickness (ft)	
Cluster 3								
Groundwater Sampling Points								
C3-PZ-1	17.0	16.5-17	No. 010	2.25	1	20/40	2.5	N/A
C3-PZ-2	15.0	14.5-15	No. 010	2.25	1	20/40	2.5	N/A
C3-PZ-3	13.0	12.5-13	No. 010	2.25	1	20/40	2.5	N/A
C3-PZ-4	11.5	11-11.5	No. 010	2.25	1	20/40	2.5	N/A
C3-PZ-5	9.5	9-9.5	No. 010	2.25	1	20/40	2.5	N/A
Soil Gas Sampling Points								
C3-SG-1	11.5	N/A	N/A	2.25	N/A	20/40	1	1/8
C3-SG-2	9.5	N/A	N/A	2.25	N/A	20/40	1	1/8
C3-SG-3	7.0	N/A	N/A	2.25	N/A	20/40	1	1/8
C3-SG-4	4.5	N/A	N/A	2.25	N/A	20/40	1	1/8
C3-SG-5	2.5	N/A	N/A	2.25	N/A	20/40	1	1/8

Notes:
1. Well locations are shown on Figure A.2.1
2. All locations were completed to the surface with a bentonite seal
3. bgs = Below ground surface.

GSI ENVIRONMENTAL

TABLE A.2.3
DEPTH TO WATER MEASUREMENTS
ESTCP Tier 2 Vapor Screening Study
Building 828, Travis Air Force Base, California

Well ID	Installed Total Depth (ft, bgs)	Screen Interval Depth (ft, bgs)	2/6/2009 Depth to Water (ft, bgs)	2/9/2009 Depth to Water (ft, bgs)	Measured Total Depth (ft, bgs)
Cluster 1					
C1-PZ-1	16.5	16-16.5	9.41	10.52	14.92
C1-PZ-2	14.5	14-14.5	13.11	11.41	13.94
C1-PZ-3	11.5	11-11.5	DRY	DRY	10.70
C1-PZ-4	10.5	10-10.5	DRY	DRY	9.96
C1-PZ-5	8.5	8-8.5	DRY	DRY	7.92
Cluster 2					
C2-PZ-1	16.5	16-16.5	14.72	11.29	16.48
C2-PZ-2	13.0	12.5-13	DRY	10.18	12.66
C2-PZ-3	10.0	9.5-10	DRY	DRY	9.56
C2-PZ-4	9.0	8.5-9	DRY	DRY	8.48
C2-PZ-5	7.5	7-7.5	DRY	5.24	6.98
Cluster 3					
C3-PZ-1	17.0	16.5-17	11.51	11.33	16.46
C3-PZ-2	15.0	14.5-15	11.11	12.20	14.39
C3-PZ-3	13.0	12.5-13	9.70	11.47	12.71
C3-PZ-4	11.5	11-11.5	DRY	DRY	10.93
C3-PZ-5	9.5	9-9.5	DRY	DRY	8.91

Notes:
1. Well locations are shown on Figure A.2.1
2. bgs = Below ground surface.

GSI ENVIRONMENTAL

TABLE A.2.4

RESULTS OF GROUNDWATER ANALYSES: COMPOUNDS OF INTEREST

ESTCP Tier 2 Vapor Screening Study

Building 828, Travis Air Force Base, California

SAMPLE LOCATION:	C1-PZ-1	*DUPLICATE* C1-PZ-1	C1-PZ-2	C2-PZ-1	C2-PZ-2	C2-PZ-5
SCREEN INTERVAL (ft, bgs):	16-16.5	16-16.5	14-14.5	16-16.5	12.5-13	7-7.5
SAMPLE DATE:	2/10/2009	2/10/2009	2/10/2009	2/10/2009	2/10/2009	2/10/2009
COMPOUND	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Volatile Organic Compounds (VOCs) by Method 8260B						
Dichloroethene, cis-1,2-	<0.001	<0.001	<0.001	**0.0014**	<0.001	<0.001
Dichloroethene, trans-1,2-	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Tetrachloroethene	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Trichloroethene	**0.0021**	**0.0019**	**0.0014**	**0.01**	**0.0027**	<0.001
Vinyl chloride	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005

SAMPLE LOCATION:	C3-PZ-1	C3-PZ-2	C3-PZ-3	Field Blank	Trip Blank
SCREEN INTERVAL (ft):	16.5-17	14.5-17	12.5-13	NA	NA
SAMPLE DATE:	2/10/2009	2/10/2009	2/10/2009	2/10/2009	NA
COMPOUND	mg/L	mg/L	mg/L	mg/L	mg/L
Volatile Organic Compounds (VOCs) by Method 8260B					
Dichloroethene, cis-1,2-	**0.031**	**0.026**	**0.022**	<0.001	<0.001
Dichloroethene, trans-1,2-	**0.0025**	**0.002**	**0.0015**	<0.001	<0.001
Tetrachloroethene	<0.001	<0.001	<0.001	<0.001	<0.001
Trichloroethene	**0.036**	**0.032**	**0.025**	<0.001	<0.001
Vinyl chloride	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005

Notes:

1. Sampling locations are shown on Figure A.2.1.
2. Samples were analyzed by Calscience Environmental Laboratories, Inc. in Garden Grove, California by Method 8260B.
3. Detected analytes are presented in **bold** type.
4. < = Not detected at detection limit shown.

GSI ENVIRONMENTAL

TABLE A.2.5
RESULTS OF SOIL GAS ANALYSES: COMPOUNDS OF INTEREST
ESTCP Tier 2 Vapor Screening Study
Building 828, Travis Air Force Base, California

SAMPLE LOCATION:	C1-SG-1	C1-SG-2	C1-SG-3	C1-SG-4	C1-SG-5	C2-SG-1	*DUPLICATE* C2-SG-1	C2-SG-2
SCREEN INTERVAL (ft, bgs):	10-10.5	8-8.5	6-6.5	4-4.5	2-2.5	8.5-9	8.5-9	7-7.5
SAMPLE DATE:	2/10/2009	2/10/2009	2/10/2009	2/10/2009	2/10/2009	2/10/2009	2/10/2009	2/10/2009
SAMPLE COLLECTION METHOD:	Syringe/Tedlar	Syringe/Tedlar	Syringe/Tedlar	Syringe/Tedlar	Syringe/Tedlar	Syringe/Tedlar	Syringe/Tedlar	Syringe/Tedlar
COMPOUND	µg/m^3	µg/m^3	µg/m^3	µg/m^3	µg/m^3	µg/m^3	µg/m^3	µg/m^3
Volatile Organic Compounds (VOCs) by Method TO-15								
Dichloroethene, cis-1,2-	<5	<5	<5	<5	<5	<5	<5	<5
Dichloropropene, trans-1,3-	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Sulfur Hexafluoride (SF6)	<6	<6	<6	<6	<6	<6	<6	<6
Tetrachloroethene	<5	<5	<5	<5	<5	<5	<5	<5
Trichloroethene	**21**	<5	<5	<5	<5	**30**	**24**	**23**

SAMPLE LOCATION:	C2-SG-3	C2-SG-4	C2-SG-5	C3-SG-1	C3-SG-2	C3-SG-3	C3-SG-4	C3-SG-5
SCREEN INTERVAL (ft, bgs):	5-5.5	3-3.5	1.5-2	11-11.5	9-9.5	6.5-7	4-4.5	2-2.5
SAMPLE DATE:	2/10/2009	2/10/2009	2/10/2009	2/10/2009	2/10/2009	2/10/2009	2/10/2009	2/10/2009
SAMPLE COLLECTION METHOD:	Syringe/Tedlar	Syringe/Tedlar	Syringe/Tedlar	Syringe/Tedlar	Syringe/Tedlar	Syringe/Tedlar	Syringe/Tedlar	Syringe/Tedlar
COMPOUND	µg/m^3	µg/m^3	µg/m^3	µg/m^3	µg/m^3	µg/m^3	µg/m^3	µg/m^3
Volatile Organic Compounds (VOCs) by Method TO-15								
Dichloroethene, cis-1,2-	<5	<5	<5	**5.1**	<5	<5	<5	<5
Dichloropropene, trans-1,3-	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005	<0.0005
Sulfur Hexafluoride (SF6)	<6	<6	<6	<6	<6	<6	<6	<6
Tetrachloroethene	<5	<5	<5	<5	<5	<5	<5	<5
Trichloroethene	**18**	<5	<5	**250**	**70**	**5**	<5	<5

Notes:
1. Sampling locations are shown on Figure A.2.1
2. Samples were analyzed by Columbia Analytical Services, Inc. in Simi Valley, California by Method TO-15 Modifie
3. Detected analytes are presented in **bold** type.
4. < = Not detected at detection limit shown.

GSI ENVIRONMENTAL

TABLE A.2.6
RESULTS OF SOIL PERMEABILITY TESTING
ESTCP Tier 2 Vapor Screening Study
Building 828, Travis Air Force Base, California

Cluster Location	Sample Point	Air Flow Rate (Q) (L/min)	Air Flow Rate (Q) (cc/min)	Vacuum (P) (in. Hg)	Vacuum (P) (in. H2O)	Slope of Q vs. P	Permeability (cm2)
Cluster 1	PZ-3	5	5000	1.0	14	374	1.03E-08
		3	3000	0.5	7		
		1	1000	0.2	2.5		
		0.5	500	0.1	1.5		
	PZ-4	10	10000	1.2	16	520	1.43E-08
		8	8000	1.0	14		
		5	5000	0.4	5		
		3	3000	0.2	2.5		
		1	1000	0.1	1		
	PZ-5	9	9000	0.6	8	865	2.38E-08
		5	5000	0.2	2.6		
		3	3000	0.1	1.5		
Cluster 2	PZ-5	5	5000	2.1	28	168	4.63E-09
		3	3000	0.9	12.5		
		1	1000	0.2	3		
		0.45	450	0.1	1.5		
Cluster 3	PZ-4	10	10000	1.4	19	510	1.40E-08
		5	5000	0.6	8		
		3	3000	0.4	6		
	PZ-5	9	9000	2.1	28	303.43	8.35E-09
		5	5000	0.8	11		
		3	3000	0.6	8		
		3	3000	0.3	4		
		1	1000	0.1	2		
		5	5000	0.7	9		
		9	9000	1.7	23		

Parameter	Symbol	Value	Units	Basis
Viscosity of air	viscosity	1.73E-04	g/cm-s (poise)	Literature (40 deg. F)
Length: Mont. Well	L	15.2	cm	Screen length for monitoring well points (6 inches)
Diameter: Mont. Well	D	3.2	cm	Inside diameter for monitoring well points
Units Conversion		1.07E-06		From calculation methods sheet
L/D Term: Well Pt		0.1486		Calculated

GSI ENVIRONMENTAL

TABLE A.2.7
SAMPLING POINT COMPLETION DETAILS: SUB-SLAB AND PRESSURE MEASUREMENT
ESTCP Tier 2 Vapor Screening Study
Building 828, Travis Air Force Base, California

Well ID	Installed Total Depth (ft, bgs)	Boring Hole Diameter (inches)	Sand Backfill Filter Pack		Tubing Diameter (inches)
			U.S. Mesh Interval	Filter Pack Thickness (in)	
Sub-Slab Sampling Points					
SS-1	0.67	1	20/40	1	1/8
SS-2	0.67	1	20/40	1	1/8
SS-3	0.67	1	20/40	1	1/8
SG-2	2.5	1	20/40	1	1/4
Pressure Measurement Points					
SS-1-P	0.67	1	20/40	1	1/4
SS-2-P	0.67	1	20/40	1	1/4
SS-3-P	0.67	1	20/40	1	1/4
SS-4-P	0.67	1	20/40	1	1/4
SG-4-2ft-P	2	1	20/40	1	1/4
SG-2-2.5ft-P	2.5	1	20/40	1	1/4

Notes:
1. Locations are shown on Figure A.2.6
2. All locations were completed to the surface with a bentonite seal
3. bgs = Below ground surface.

GSI ENVIRONMENTAL

TABLE A.2.8
RESULTS OF SUB-SLAB ANALYSES: COMPOUNDS OF INTEREST
ESTCP Tier 2 Vapor Screening Study
Building 828, Travis Air Force Base, California

		DUPLICATE							
SAMPLE LOCATION:	SubSlab-1	SubSlab-1	SubSlab-1	SubSlab-2	SubSlab-2	SubSlab-3	SubSlab-3	SG-2	SG-2
PRESSURE CONDITION:	Negative	Negative	Positive	Negative	Positive	Negative	Positive	Negative	Positive
SAMPLE DEPTH (ft bgs):	0.67	0.67	0.67	0.67	0.67	0.67	0.67	2.5	2.5
SAMPLE DATE:	2/11/2009	2/11/2009	2/12/2009	2/11/2009	2/12/2009	2/11/2009	2/12/2009	2/11/2009	2/12/2009
COMPOUND	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$
Volatile Organic Compounds (VOCs) by Method TO-15									
Benzene	<0.41	<0.4	<0.4	<0.41	<0.41	**0.47**	<0.41	**0.97**	<0.4
Toluene	<2	<2	<2	<2	<2.1	<2.1	<2	**4**	**2.5**
Dichloroethene, cis-1,2-	<0.41	<0.4	<0.4	<0.41	<0.41	<0.41	<0.41	<0.41	<0.4
Dichloroethene, trans-1,2-	<0.41	<0.4	<0.4	<0.41	<0.41	<0.41	<0.41	<0.41	<0.4
Tetrachloroethene	<0.41	<0.4	<0.4	**0.55**	**0.59**	**1.6**	**1.6**	**0.41**	**0.61**
Trichloroethene	<0.41	<0.4	<0.4	<0.41	<0.41	**2.7**	**2.4**	<0.41	<0.4
Vinyl Chloride	<0.41	<0.4	<0.4	<0.41	<0.41	<0.41	<0.41	<0.41	<0.4
NIOSH 6602									
Sulfur Hexafluoride (SF6)	<9.7	<9.6	**11**	<9.7	<9.8	<9.9	<9.7	**47**	**16**
Radon									
Radon pCi/L	**739**	**736**	**825***	**1232**	**1105**	**963**	**984**	**843**	**1091**

Notes:
1. VOC and SF6 samples were analyzed by Columbia Analytical Services, Inc. in Simi Valley, California. Radon analysis by US(
2. Detected analytes are presented in **bold** type.
3. < = not detected at detection limit shown.
4. * = value is the average between actual sample and its duplicate
5. Compounds shown include those i) detected in groundwater samples collected for Tier 2 or ii) evaluated in Tier 3 pressure control demonstration.

TABLE A.2.9

RESULTS OF INDOOR AND AMBIENT AIR ANALYSES: COMPOUNDS OF INTEREST

ESTCP Tier 2 Vapor Screening Study

Building 828, Travis Air Force Base, California

SAMPLE LOCATION:	Indoor-1	*DUPLICATE* Indoor-1	Indoor-1	Indoor-2	Indoor-2	Indoor-3	Indoor-3	Ambient-1	Ambient-2
PRESSURE CONDITION:	Negative	Negative	Positive	Negative	Positive	Negative	Positive	Negative	Positive
SAMPLE DATE:	2/11/2009	2/11/2009	2/12/2009	2/11/2009	2/12/2009	2/11/2009	2/12/2009	2/11/2009	2/12/2009
COMPOUND	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$
Volatile Organic Compounds (VOCs) by Method TO-15 SIM									
Benzene	**0.55**	**0.88**	**0.61**	**0.55**	**0.5**	**0.52**	**0.51**	**0.7**	**0.5**
Toluene	**1.2**	**1.9**	**0.93**	**1.3**	**0.74**	**0.83**	**0.65**	**1.3**	**0.53**
Dichloroethene, cis-1,2-	**0.047**	**0.041**	<0.038	<0.036	<0.032	<0.041	<0.038	<0.038	<0.037
Dichloroethene, trans-1,2-	<0.037	<0.037	<0.038	<0.036	<0.032	<0.041	<0.038	<0.038	<0.037
Tetrachloroethene	**0.066**	**0.069**	**0.061**	**0.059**	**0.038**	**0.072**	<0.038	**0.058**	<0.037
Trichloroethene	**0.25**	**0.24**	<0.038	**0.11**	<0.032	**0.1**	<0.038	<0.038	<0.037
Vinyl Chloride	<0.037	<0.037	<0.038	<0.036	<0.032	<0.041	<0.038	<0.038	<0.037
NIOSH 6602									
Sulfur Hexafluoride (SF6)	**110**	**110**	**90**	**90**	**68**	**76**	**9.4**	<9.1	<8.9
Radon									
Radon (pCi/L)	**0.7**	--	**0.3**	**0.7**	**0.2**	**0.6**	**0.3**	**0.4**	**0.3**

Notes:

1. VOC and SF6 samples were analyzed by Columbia Analytical Services, Inc. in Simi Valley, California. Radon by USC.
2. Detected analytes are presented in **bold** type.
3. < = not detected at detection limit shown.
4. -- = not available
5. Compounds shown include those i) detected in groundwater samples collected for Tier 2 or ii) evaluated in Tier 3 pressure control demonstration.

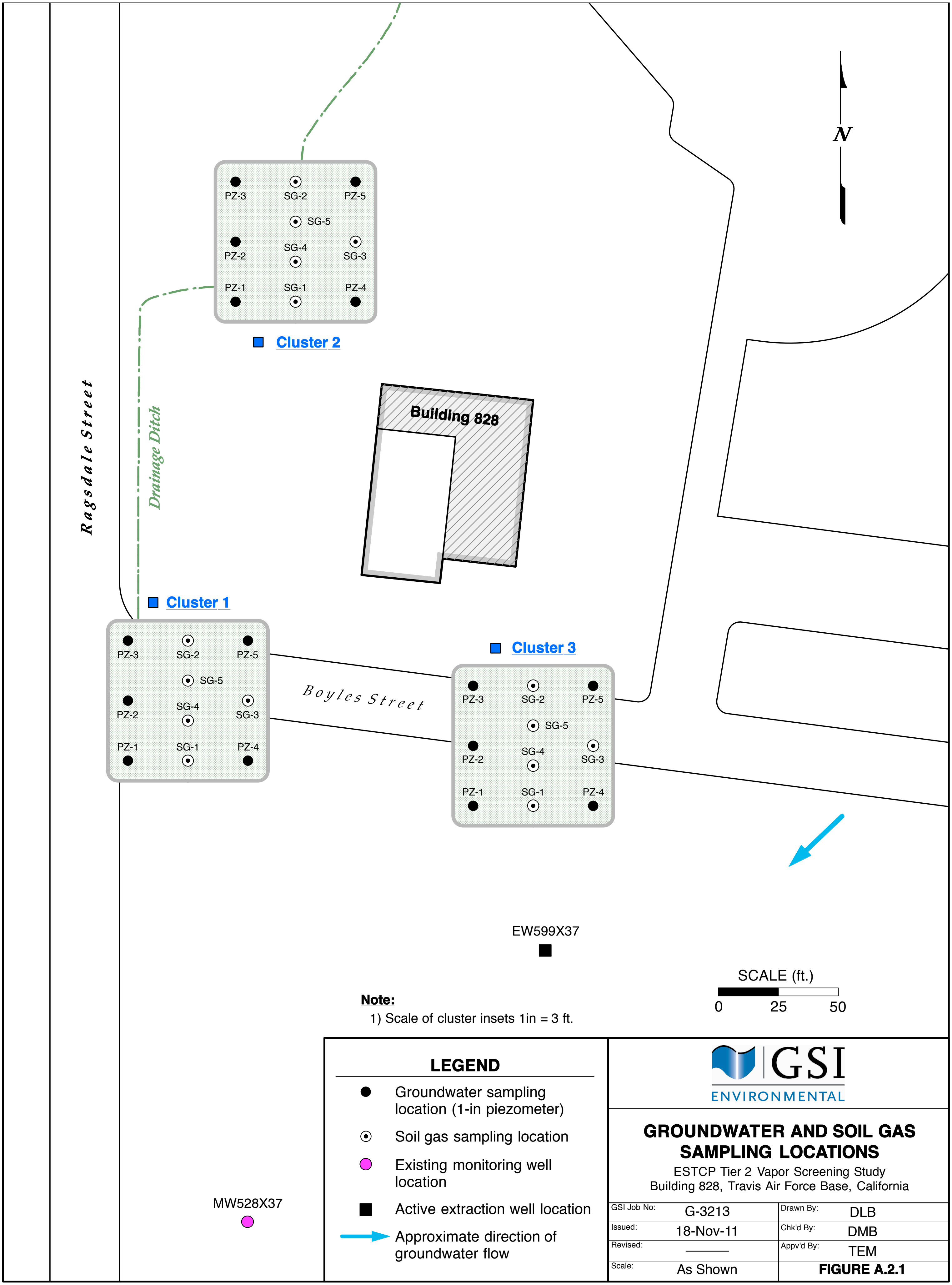
GSI ENVIRONMENTAL

TABLE A.2.10
PRESSURE GRADIENT MEASUREMENTS FROM ADDITIONAL LOCATIONS
ESTCP Tier 2 Vapor Screening Study
Building 828, Travis Air Force Base, California

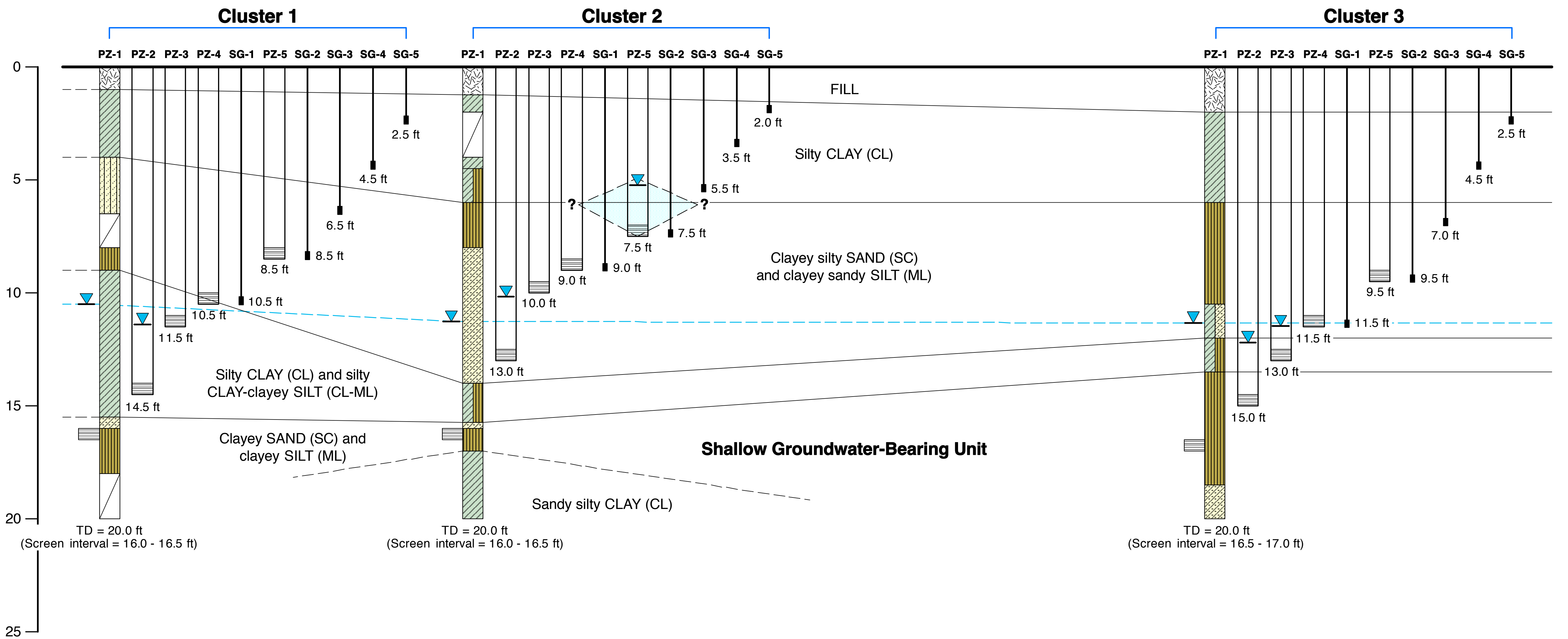
	Pressure Gradient (Pa)								
Condition	Time	Window	Backdoor	SS-1	SS-2	SG-2-2.5 ft	SS-3	SS-4	SG-4-2.0 ft
Depressurization w/ large fan	2/9/2009 10:00	-34.86	-34.86	-	-	-	0	-0.747	-
Depressurization w/ large fan	2/10/2009 14:00	-39.84	-	-1.743	-1.743	-1.743	-1.245	-0.747	-0.498

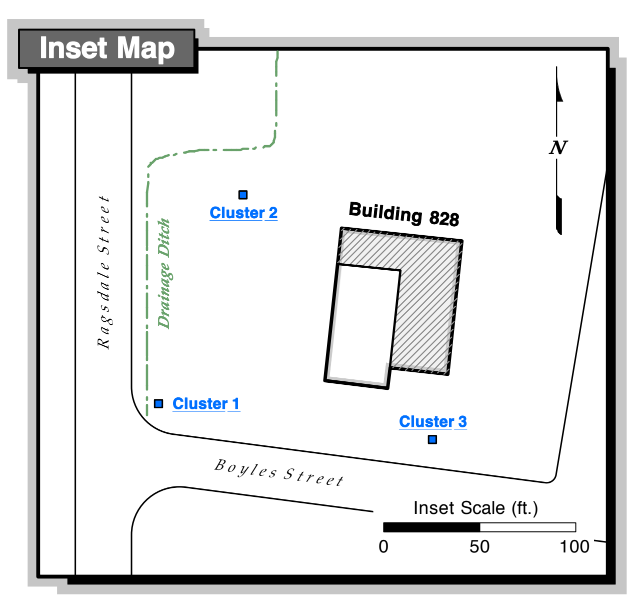
Note:

Hand recorded readings from pressure transducer.



N
Ragsdale Street
Drainage Ditch
Boyles Street
Building 828
Cluster 1
Cluster 2
Cluster 3
PZ-3
SG-2
PZ-5
SG-5
PZ-2
SG-4
SG-3
PZ-1
SG-1
PZ-4
EW599X37
MW528X37
SCALE (ft.)
0
25
50
Note:
1) Scale of cluster insets 1in = 3 ft.
LEGEND
Groundwater sampling location (1-in piezometer)
Soil gas sampling location
Existing monitoring well location
Active extraction well location
Approximate direction of groundwater flow
GSI
ENVIRONMENTAL
GROUNDWATER AND SOIL GAS SAMPLING LOCATIONS
ESTCP Tier 2 Vapor Screening Study
Building 828, Travis Air Force Base, California
GSI Job No: G-3213
Drawn By: DLB
Issued: 18-Nov-11
Chk'd By: DMB
Revised: ———
Appv'd By: TEM
Scale: As Shown
FIGURE A.2.1





LEGEND

- FILL
- Silty CLAY (CL)
- Clayey SAND (SC)
- Silty SAND (SM)
- Clayey SILT (ML)
- No Recovery
- Potential perched groundwater
- Screen interval
- Static water level, as measured on 9-Feb-09
- Potentiometric surface based on static water levels measured on 9-Feb-09

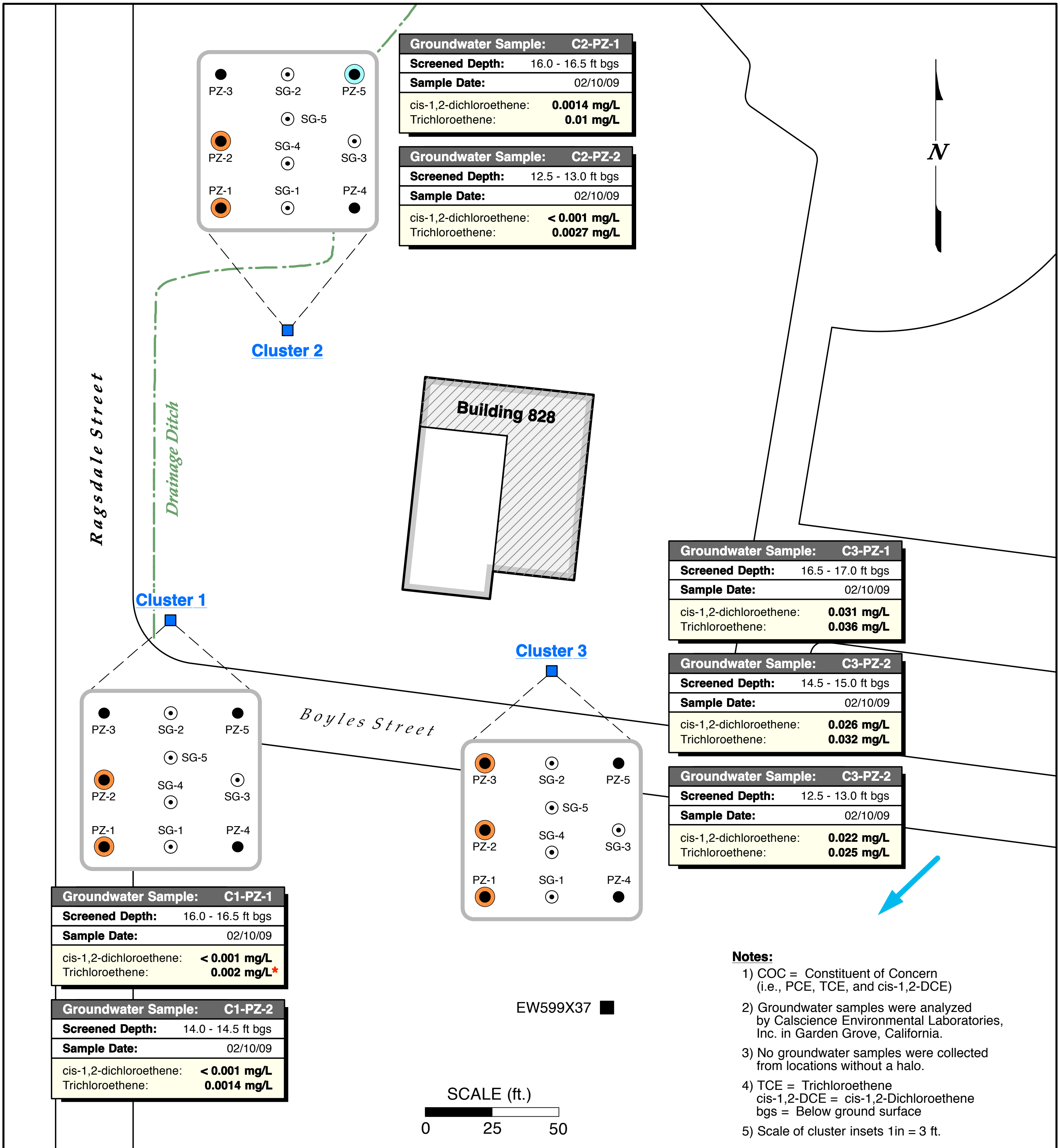
Note: To illustrate the entire lithology at C1-PZ-1, C2-PZ-1, and C3-PZ-1, the screen interval is presented adjacent to the lithology.

GSI ENVIRONMENTAL

CONCEPTUAL CROSS-SECTION OF SUBSURFACE SAMPLE POINTS AND SHALLOW GEOLOGY

ESTCP Tier 2 Vapor Screening Study
Building 828, Travis Air Force Base, California

GSI Job No:	G-3213	Drawn By:	DLB
Issued:	18-Nov-11	Chk'd By:	DMB
Revised:	———	Appv'd By:	LMB
Scale:	As Shown		**FIGURE A.2.2**



Groundwater Sample:	C2-PZ-1
Screened Depth:	16.0 - 16.5 ft bgs
Sample Date:	02/10/09
cis-1,2-dichloroethene:	0.0014 mg/L
Trichloroethene:	0.01 mg/L

Groundwater Sample:	C2-PZ-2
Screened Depth:	12.5 - 13.0 ft bgs
Sample Date:	02/10/09
cis-1,2-dichloroethene:	< 0.001 mg/L
Trichloroethene:	0.0027 mg/L

Groundwater Sample:	C3-PZ-1
Screened Depth:	16.5 - 17.0 ft bgs
Sample Date:	02/10/09
cis-1,2-dichloroethene:	0.031 mg/L
Trichloroethene:	0.036 mg/L

Groundwater Sample:	C3-PZ-2
Screened Depth:	14.5 - 15.0 ft bgs
Sample Date:	02/10/09
cis-1,2-dichloroethene:	0.026 mg/L
Trichloroethene:	0.032 mg/L

Groundwater Sample:	C3-PZ-2
Screened Depth:	12.5 - 13.0 ft bgs
Sample Date:	02/10/09
cis-1,2-dichloroethene:	0.022 mg/L
Trichloroethene:	0.025 mg/L

Groundwater Sample:	C1-PZ-1
Screened Depth:	16.0 - 16.5 ft bgs
Sample Date:	02/10/09
cis-1,2-dichloroethene:	< 0.001 mg/L
Trichloroethene:	0.002 mg/L*

Groundwater Sample:	C1-PZ-2
Screened Depth:	14.0 - 14.5 ft bgs
Sample Date:	02/10/09
cis-1,2-dichloroethene:	< 0.001 mg/L
Trichloroethene:	0.0014 mg/L

Notes:

1) COC = Constituent of Concern (i.e., PCE, TCE, and cis-1,2-DCE)
2) Groundwater samples were analyzed by Calscience Environmental Laboratories, Inc. in Garden Grove, California.
3) No groundwater samples were collected from locations without a halo.
4) TCE = Trichloroethene
   cis-1,2-DCE = cis-1,2-Dichloroethene
   bgs = Below ground surface
5) Scale of cluster insets 1in = 3 ft.

LEGEND

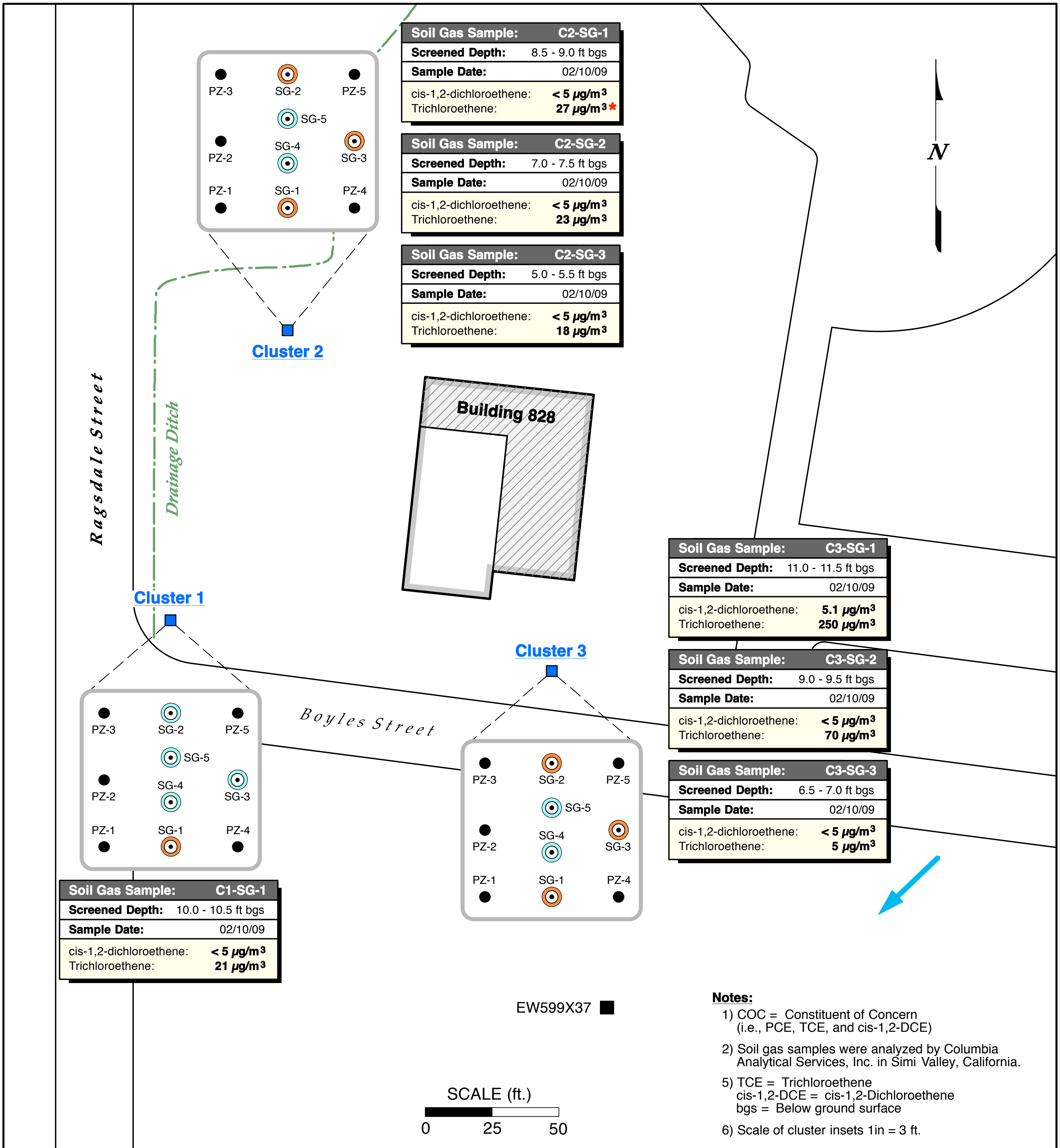
- Groundwater sampling location (1-in piez.)
- Soil gas sampling location
- Existing monitoring well location
- One or more COCs detected above the reporting limit
- COCs not detected
- * Duplicate samples taken; average value shown
- Active extraction well location
- Approximate direction of groundwater flow

GSI ENVIRONMENTAL

GROUNDWATER SAMPLING AND TESTING RESULTS

ESTCP Tier 2 Vapor Screening Study
Building 828, Travis Air Force Base, California

GSI Job No: G-3213		Drawn By: DLB	
Issued: 18-Nov-11		Chk'd By: DMB	
Revised: ————		Appv'd By: LMB	
Scale: As Shown		**FIGURE A.2.3**	



Notes:

1) COC = Constituent of Concern (i.e., PCE, TCE, and cis-1,2-DCE)

2) Soil gas samples were analyzed by Columbia Analytical Services, Inc. in Simi Valley, California.

5) TCE = Trichloroethene
cis-1,2-DCE = cis-1,2-Dichloroethene
bgs = Below ground surface

6) Scale of cluster insets 1in = 3 ft.

MW528X37

LEGEND

- Groundwater sampling location (1-in piez.)
- Soil gas sampling location
- Existing monitoring well location
- One or more COCs detected above the reporting limit
- COCs not detected
- * Duplicate samples taken; average value shown
- Active extraction well location
- Approximate direction of groundwater flow

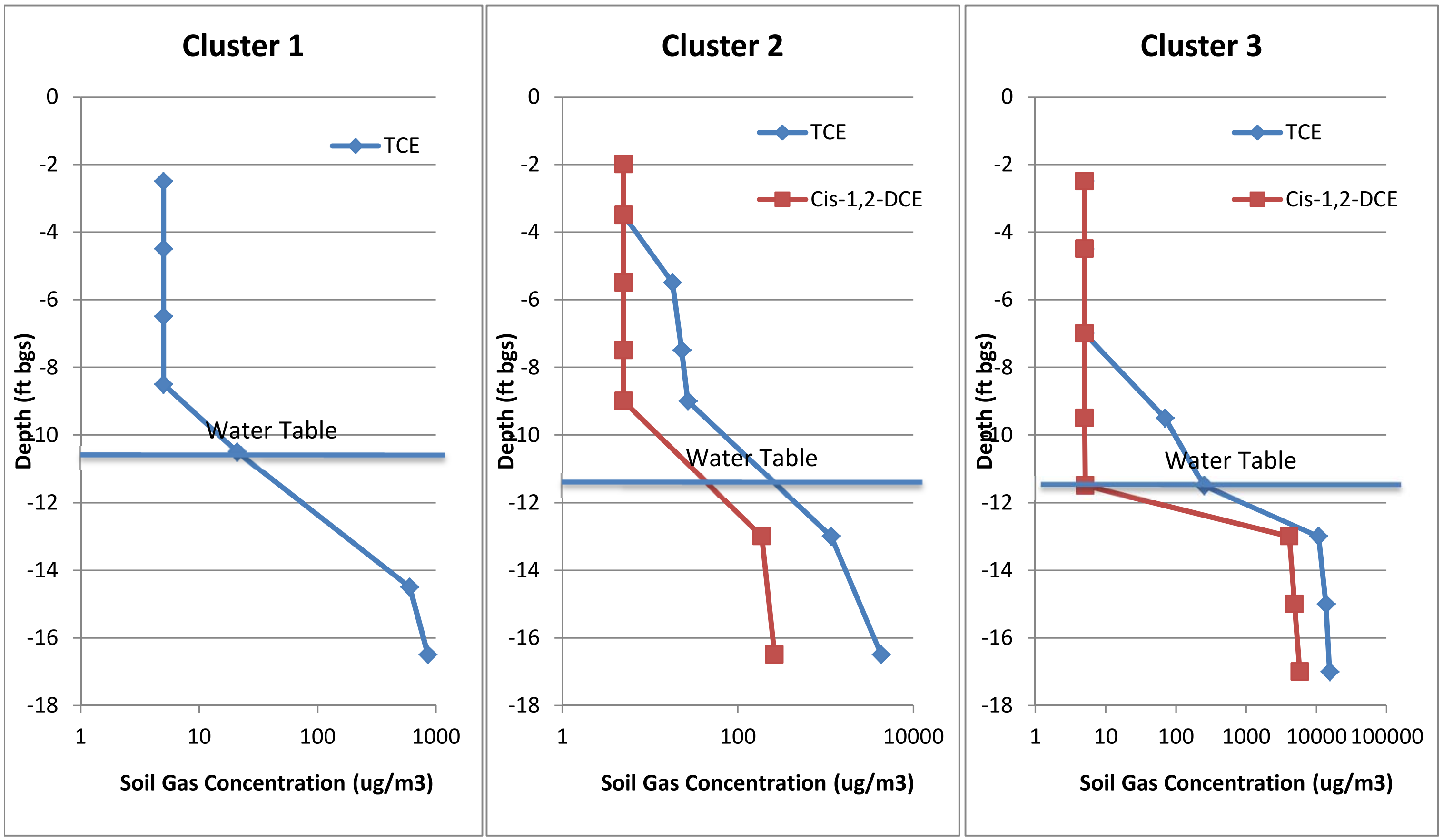
GSI ENVIRONMENTAL

SOIL GAS SAMPLING AND TESTING RESULTS

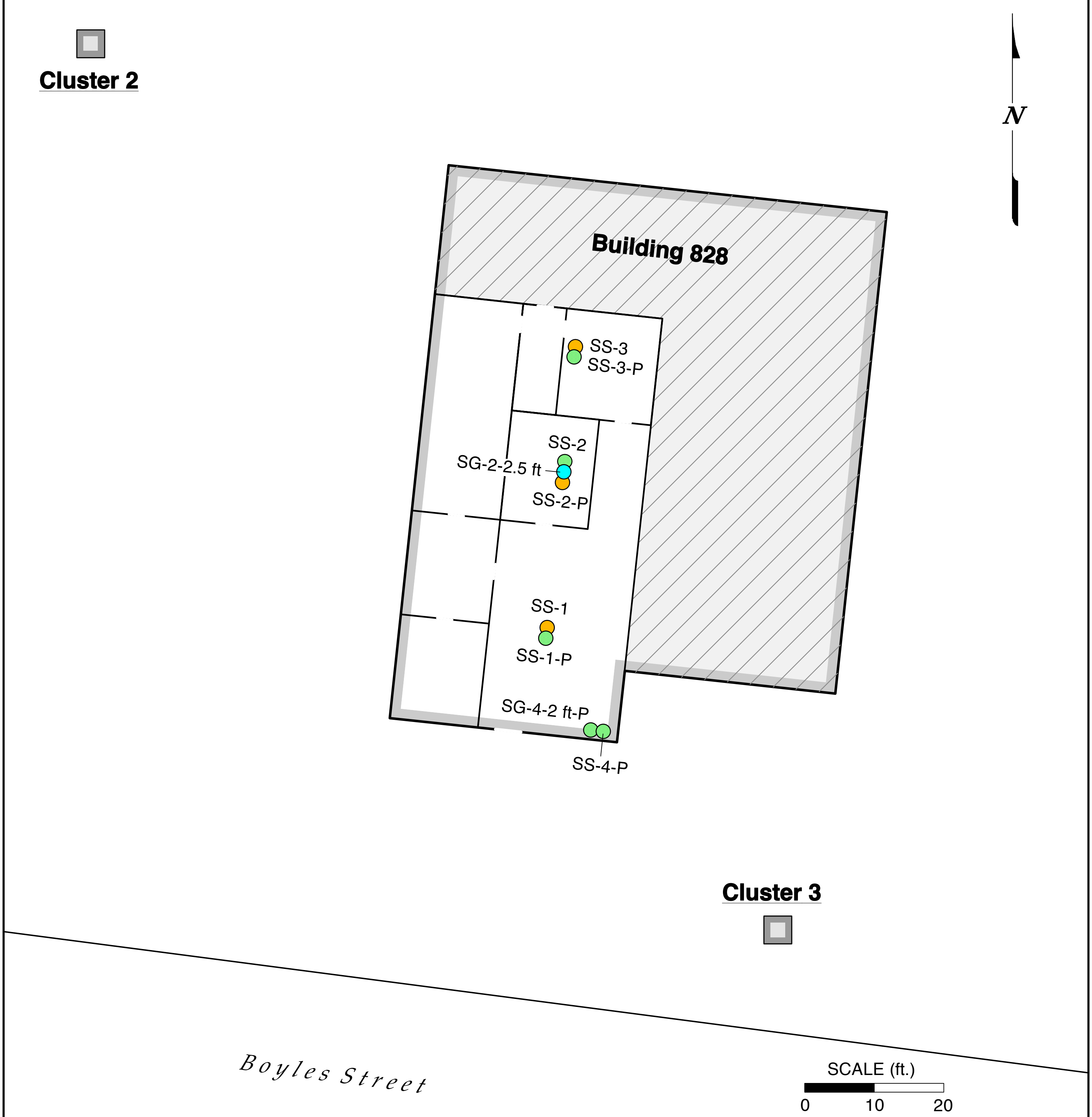
ESTCP Tier 2 Vapor Screening Study
Building 828, Travis Air Force Base, California

GSI Job No: G-3213		Drawn By: DLB	
Issued: 18-Nov-11		Chk'd By: DMB	
Revised: ————		Appv'd By: LMB	
Scale: As Shown		FIGURE A.2.4	

FIGURE A.2.5
VERTICAL VOC PROFILE
ESTCP Tier 2 Vapor Screening Study
Travis Air Force Base, California



* = Concentrations in groundwater (i.e., below the water table) were converted into equivalent soil gas concentrations using Henry's Law assuming equilibrium partitioning.



LEGEND

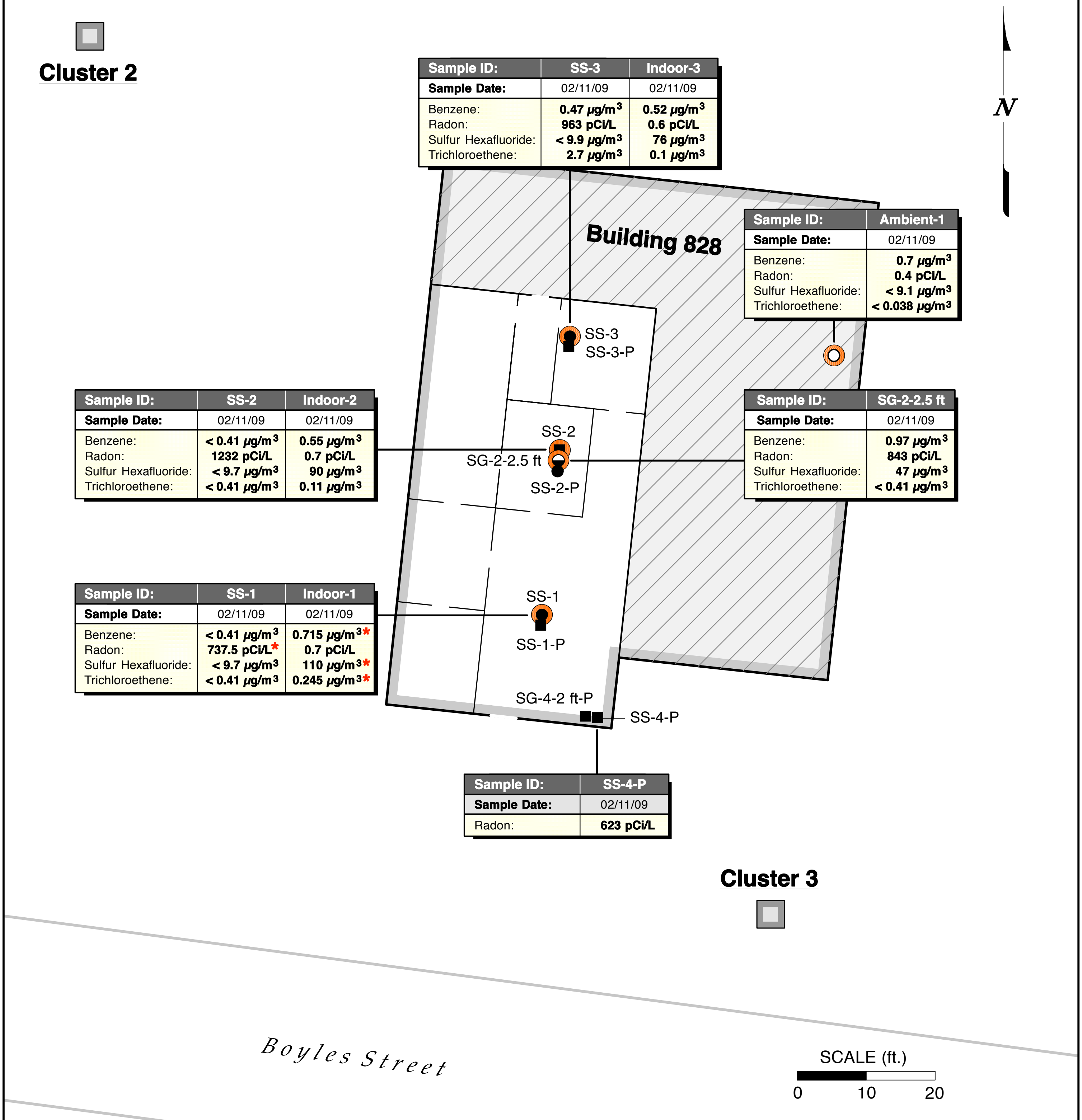
- Sub-slab sampling point
- Pressure measurement point
- Both sub-slab and pressure measurement point

GSI ENVIRONMENTAL

SUB-SLAB SAMPLING AND PRESSURE MEASUREMENT LOCATIONS

ESTCP Tier 2 Vapor Screening Study
Building 828, Travis Air Force Base, California

GSI Job No: G-3213		Drawn By: DLB	
Issued: 18-Nov-11		Chk'd By: DMB	
Revised: ———		Appv'd By: TEM	
Scale: As Shown		**FIGURE A.2.6**	



Sample ID:	SS-3	Indoor-3
Sample Date:	02/11/09	02/11/09
Benzene:	**0.47 µg/m³**	**0.52 µg/m³**
Radon:	**963 pCi/L**	**0.6 pCi/L**
Sulfur Hexafluoride:	**< 9.9 µg/m³**	**76 µg/m³**
Trichloroethene:	**2.7 µg/m³**	**0.1 µg/m³**

Sample ID:	Ambient-1
Sample Date:	02/11/09
Benzene:	**0.7 µg/m³**
Radon:	**0.4 pCi/L**
Sulfur Hexafluoride:	**< 9.1 µg/m³**
Trichloroethene:	**< 0.038 µg/m³**

Sample ID:	SS-2	Indoor-2
Sample Date:	02/11/09	02/11/09
Benzene:	**< 0.41 µg/m³**	**0.55 µg/m³**
Radon:	**1232 pCi/L**	**0.7 pCi/L**
Sulfur Hexafluoride:	**< 9.7 µg/m³**	**90 µg/m³**
Trichloroethene:	**< 0.41 µg/m³**	**0.11 µg/m³**

Sample ID:	SG-2-2.5 ft
Sample Date:	02/11/09
Benzene:	**0.97 µg/m³**
Radon:	**843 pCi/L**
Sulfur Hexafluoride:	**47 µg/m³**
Trichloroethene:	**< 0.41 µg/m³**

Sample ID:	SS-1	Indoor-1
Sample Date:	02/11/09	02/11/09
Benzene:	**< 0.41 µg/m³**	**0.715 µg/m³***
Radon:	**737.5 pCi/L***	**0.7 pCi/L**
Sulfur Hexafluoride:	**< 9.7 µg/m³**	**110 µg/m³***
Trichloroethene:	**< 0.41 µg/m³**	**0.245 µg/m³***

Sample ID:	SS-4-P
Sample Date:	02/11/09
Radon:	**623 pCi/L**

LEGEND

- ● Sub-slab sampling point
- ■ Pressure measurement point
- ◒ Both sub-slab and pressure measurement point
- ○ Ambient air sampling point
- One or more COCs detected above the reporting limit in the sub-slab and/or indoor air sample
- COCs not detected
- * Duplicate samples taken; average value shown

Notes:

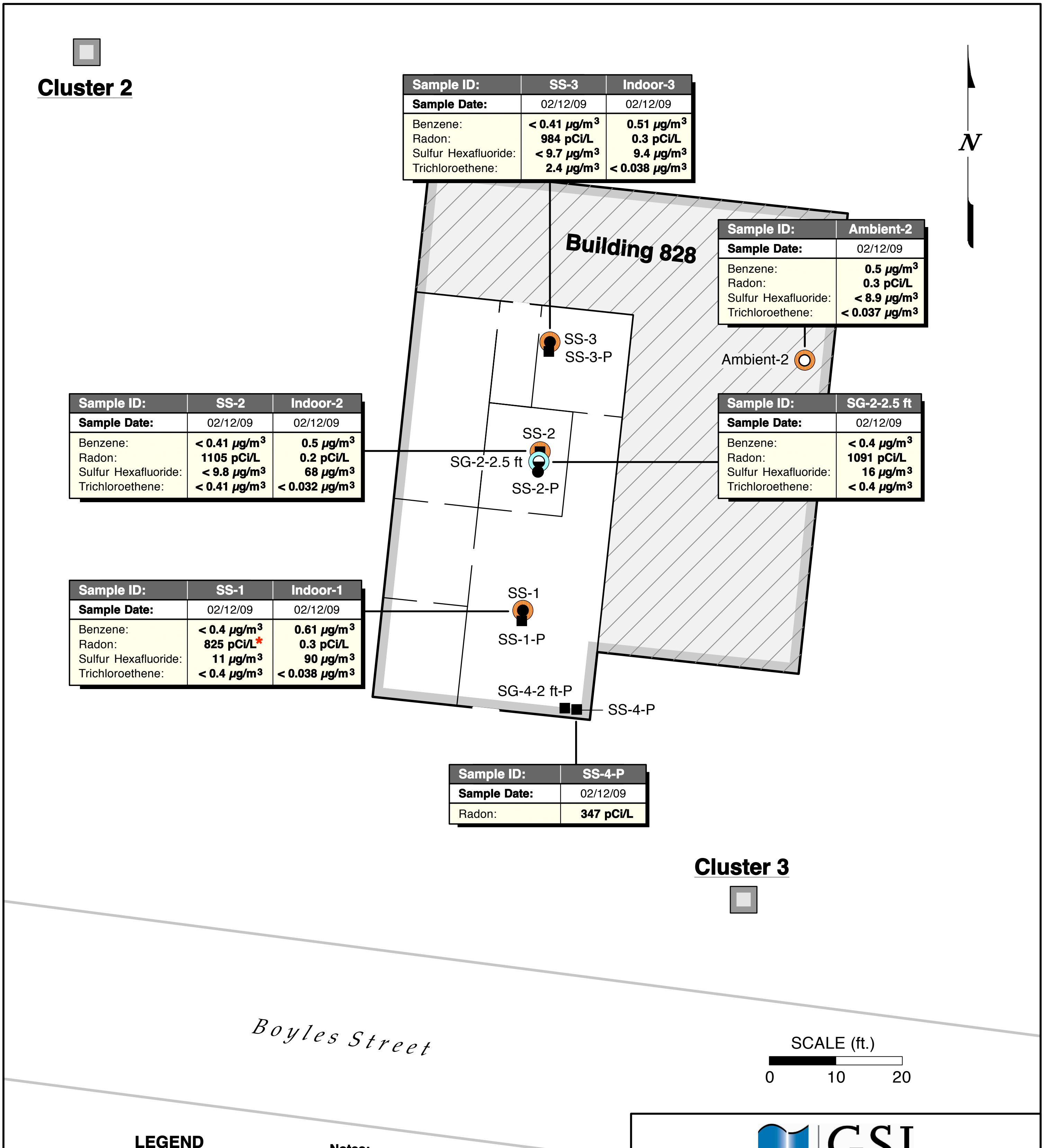
1) COC = Constituent of Concern
2) COCs include benzene and TCE. SF_6 and radon were used as tracer gases.
3) Sub-slab and indoor air samples were analyzed by Columbia Analytical Services, Inc. in Simi Valley, California.
4) Indoor air samples were collected adjacent to the sub-slab location.
5) Sub-slab samples, SS-1, SS-2, and SS-3 were collected 8 inches below the slab.
6) SS-4-P was only sampled for radon.
7) TCE = Trichloroethene
   SF_6 = Sulfur Hexafluoride

GSI ENVIRONMENTAL

SUB-SLAB AND INDOOR AIR SAMPLING AND TESTING RESULTS: NEGATIVE PRESSURE

ESTCP Tier 2 Vapor Screening Study
Building 828, Travis Air Force Base, California

GSI Job No:	G-3213	Drawn By:	DLB
Issued:	18-Nov-11	Chk'd By:	DMB
Revised:	———	Appv'd By:	LMB
Scale:	As Shown		**FIGURE A.2.7**



Sample ID:	SS-3	Indoor-3
Sample Date:	02/12/09	02/12/09
Benzene:	**< 0.41 μg/m³**	**0.51 μg/m³**
Radon:	**984 pCi/L**	**0.3 pCi/L**
Sulfur Hexafluoride:	**< 9.7 μg/m³**	**9.4 μg/m³**
Trichloroethene:	**2.4 μg/m³**	**< 0.038 μg/m³**

Sample ID:	Ambient-2
Sample Date:	02/12/09
Benzene:	**0.5 μg/m³**
Radon:	**0.3 pCi/L**
Sulfur Hexafluoride:	**< 8.9 μg/m³**
Trichloroethene:	**< 0.037 μg/m³**

Sample ID:	SS-2	Indoor-2
Sample Date:	02/12/09	02/12/09
Benzene:	**< 0.41 μg/m³**	**0.5 μg/m³**
Radon:	**1105 pCi/L**	**0.2 pCi/L**
Sulfur Hexafluoride:	**< 9.8 μg/m³**	**68 μg/m³**
Trichloroethene:	**< 0.41 μg/m³**	**< 0.032 μg/m³**

Sample ID:	SG-2-2.5 ft
Sample Date:	02/12/09
Benzene:	**< 0.4 μg/m³**
Radon:	**1091 pCi/L**
Sulfur Hexafluoride:	**16 μg/m³**
Trichloroethene:	**< 0.4 μg/m³**

Sample ID:	SS-1	Indoor-1
Sample Date:	02/12/09	02/12/09
Benzene:	**< 0.4 μg/m³**	**0.61 μg/m³**
Radon:	**825 pCi/L***	**0.3 pCi/L**
Sulfur Hexafluoride:	**11 μg/m³**	**90 μg/m³**
Trichloroethene:	**< 0.4 μg/m³**	**< 0.038 μg/m³**

Sample ID:	SS-4-P
Sample Date:	02/12/09
Radon:	**347 pCi/L**

LEGEND

- ● Sub-slab sampling point
- ■ Pressure measurement point
- ◒ Both sub-slab and pressure measurement point
- ○ Ambient air sampling point
- (orange circle) One or more COCs detected above the reporting limit in the sub-slab and/or indoor air sample
- (light blue circle) COCs not detected
- * Duplicate samples taken; average value shown

Notes:

1) COC = Constituent of Concern
2) COCs include benzene and TCE. SF_6 and radon were used as tracer gases.
3) Sub-slab and indoor air samples were analyzed by Columbia Analytical Services, Inc. in Simi Valley, California.
4) Indoor air samples were collected adjacent to the sub-slab location.
5) Sub-slab samples, SS-1, SS-2, and SS-3 were collected 8 inches below the slab.
6) SS-4-P was only sampled for radon.
7) TCE = Trichloroethene
SF_6 = Sulfur Hexafluoride

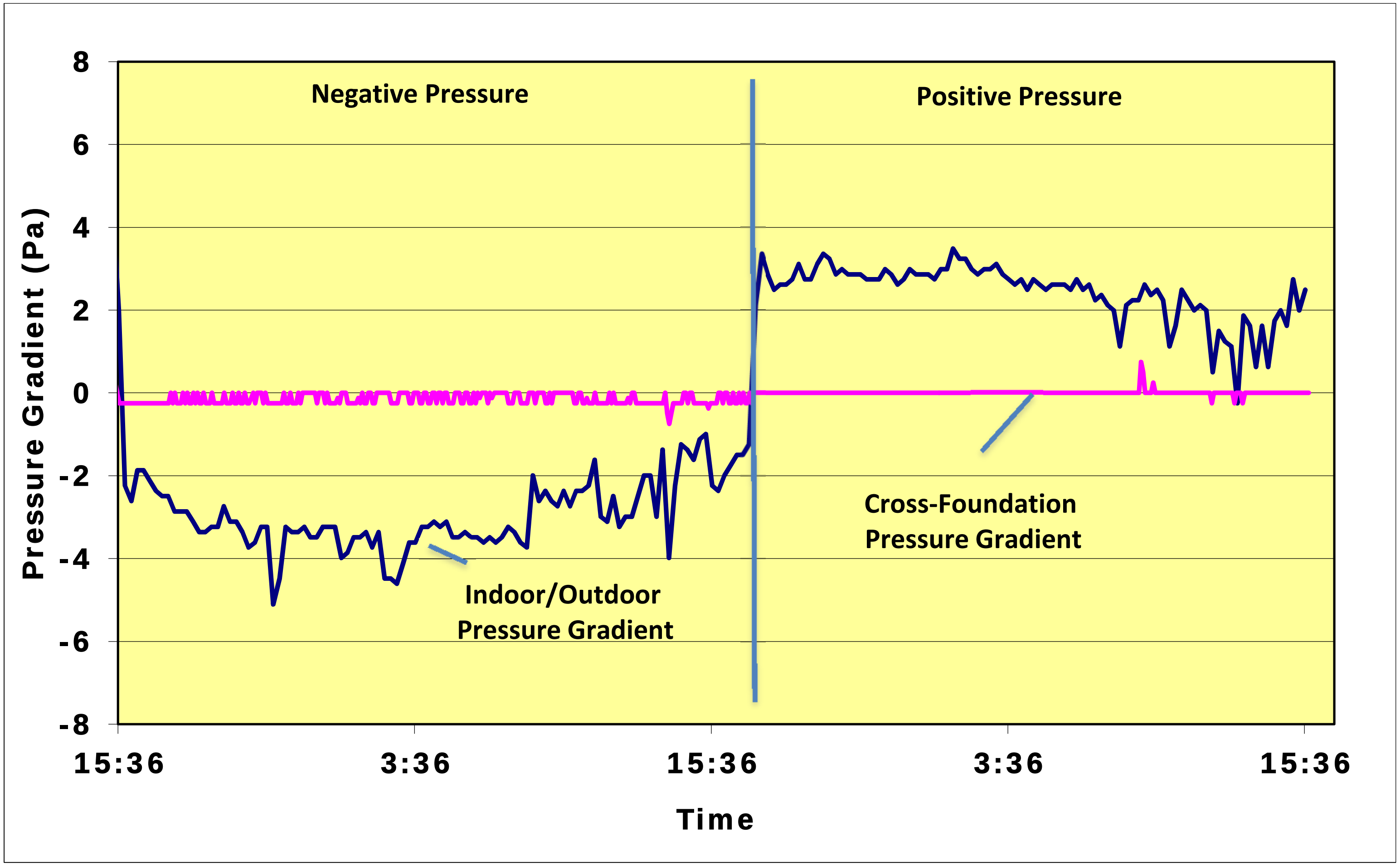
GSI ENVIRONMENTAL

SUB-SLAB AND INDOOR AIR SAMPLING AND TESTING RESULTS: POSITIVE PRESSURE

ESTCP Tier 2 Vapor Screening Study
Building 828, Travis Air Force Base, California

GSI Job No:	G-3213	Drawn By:	DLB
Issued:	18-Nov-11	Chk'd By:	DMB
Revised:	———	Appv'd By:	LMB
Scale:	As Shown		**FIGURE A.2.8**

FIGURE A.2.9
BUILDING PRESSURE GRADIENTS
ESTCP Tier 2 Vapor Screening Study
Travis Air Force Base, California



Environmental Security Technology Certification Program
(ESTCP)

FINAL REPORT

Proposed Tier 2 Screening Criteria and Tier 3 Field Procedures for Evaluation of Vapor Intrusion
ESTCP Project ER-200707

Appendix A.3: Jacksonville Naval Air Station, Florida

TABLES

FIGURES

GSI ENVIRONMENTAL

TABLE A.3.1
SAMPLING POINT COMPLETION DETAILS: SUB-SLAB AND PRESSURE MEASUREMENT
ESTCP Tier 2 Vapor Screening Study
Building 103, Yorktown and Ranger, Jacksonville NAS, Jacksonville, FL

Well ID	Installed Total Depth (ft, bgs)	Boring Hole Diameter (inches)	Sand Backfill Filter Pack		Tubing Diameter (inches)
			U.S. Mesh Interval	Filter Pack Thickness (in)	
Sub-Slab Sampling Points					
SS-1	0.67	1	20/40	1	1/4
SS-2	0.67	1	20/40	1	1/4
SS-3	0.67	1	20/40	1	1/4
SG-2	2.5	1	20/40	1	1/4
Pressure Measurement Points					
SS-1-P	0.67	1	20/40	1	1/4
SS-2-P	0.67	1	20/40	1	1/4
SS-3-P	0.67	1	20/40	1	1/4
SG-2-P	2.5	1	20/40	1	1/4

Notes:
1. Locations are shown on Figure A.3.1.
2. All locations were completed to the surface with a bentonite seal.
3. bgs = Below ground surface.

GSI ENVIRONMENTAL

TABLE A.3.2
RESULTS OF SUB-SLAB ANALYSES: COMPOUNDS OF INTEREST
ESTCP Tier 2 Vapor Screening Study
Building 103, Yorktown and Ranger, Jacksonville NAS, Jacksonville, FL

				DUPLICATE					
SAMPLE LOCATION:	SubSlab-1	SubSlab-1	SubSlab-2	SubSlab-2	SubSlab-2	SubSlab-3	SubSlab-3	SG-2	SG-2
PRESSURE CONDITION:	Negative	Positive	Negative	Negative	Positive	Negative	Positive	Negative	Positive
SAMPLE DEPTH (ft bgs):	0.67	0.67	0.67	0.67	0.67	0.67	0.67	2.5	2.5
SAMPLE DATE:	3/17/2009	3/18/2009	3/17/2009	3/17/2009	3/18/2009	3/17/2009	3/18/2009	3/17/2009	3/18/2009
COMPOUND	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$
Volatile Organic Compounds (VOCs) by Method TO-15									
Benzene	<24	<34	<34	<35	<19	<11	<12	<24	<43
Toluene	<120	<170	<170	<170	<96	<56	<60	<120	<210
Tetrachloroethene	**28,000**	**28,000**	**21,000**	**22,000**	**18,000**	**9,600**	**12,000**	**32,000**	**36,000**
Trichloroethene	**4,400**	**3,500**	**2,900**	**2,800**	**2,400**	**1,900**	**2,000**	**4,100**	**3,900**
NIOSH 6602									
Sulfur Hexafluoride (SF6)	<10	**17**	**17**	**16**	**36**	<10	<10	<10	<10
Radon									
Radon (pCi/L)	**150**	**134**	**122**	**127**	**95**	**99**	**154**	**172**	**191**

Notes:
1. VOC and SF6 samples were analyzed by Columbia Analytical Services, Inc. in Simi Valley, California. Radon analysis by USC.
2. Detected analytes are presented in **bold** type.
3. < = not detected at detection limit shown.
4. Compounds shown are those included in Tier 3 pressure control evaluation.

GSI ENVIRONMENTAL

TABLE A.3.3
RESULTS OF INDOOR AND AMBIENT AIR ANALYSES: COMPOUNDS OF INTEREST
ESTCP Tier 2 Vapor Screening Study
Building 103, Yorktown and Ranger, Jacksonville NAS, Jacksonville, FL

SAMPLE LOCATION:	Indoor-1	Indoor-1	Indoor-2	*DUPLICATE* Indoor-2	Indoor-2	Indoor-3	Indoor-3	Ambient-1	Ambient-2
PRESSURE CONDITION:	Negative	Positive	Negative	Negative	Positive	Negative	Positive	Negative	Positive
SAMPLE DATE:	3/17/2009	3/18/2009	3/17/2009	3/17/2009	3/18/2009	3/17/2009	3/18/2009	3/17/2009	3/18/2009
COMPOUND	µg/m^3	µg/m^3	µg/m^3	µg/m^3	µg/m^3	µg/m^3	µg/m^3	µg/m^3	µg/m^3
Volatile Organic Compounds (VOCs) by Method TO-15 SIM									
Benzene	**0.55**	**0.72**	**0.6**	**0.58**	**0.75**	**0.58**	**0.73**	**0.63**	**0.56**
Toluene	**2.7**	**5.8**	**3.1**	**3.2**	**3.4**	**3.8**	**3.5**	**2.1**	**1.5**
Tetrachloroethene	**1.4**	**0.54**	**1.9**	**1.9**	**0.94**	**1.7**	**0.75**	**0.15**	**0.14**
Trichloroethene	**0.29**	**0.3**	**0.45**	**0.43**	**0.2**	**0.4**	**0.18**	**0.12**	<0.04
NIOSH 6602									
Sulfur Hexafluoride (SF6)	**320**	**290**	**66**	**65**	**120**	**91**	**100**	<9.2	<9.4
Radon									
Radon (pCi/L)	**0.4**	**0.1**	**0.2**	**--**	**0**	**0.1**	**0**	**0.1**	**0**

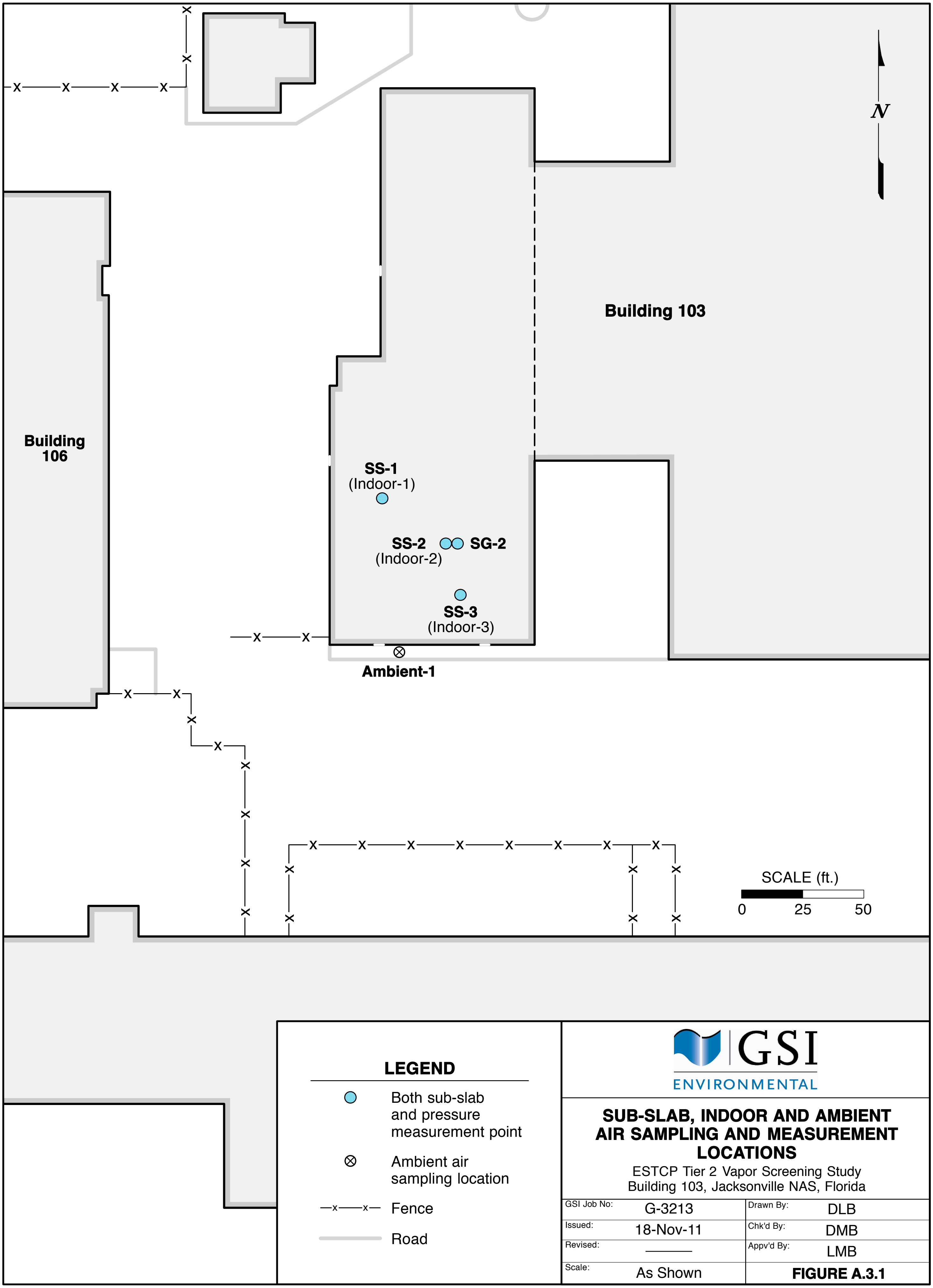
Notes:
1. VOC and SF6 samples were analyzed by Columbia Analytical Services, Inc. in Simi Valley, California by Method TO-15 and NIOSH 6602. Radon analysis by USC.
2. Detected analytes are presented in **bold** type.
3. < = not detected at detection limit shown.
4. -- = not available
5. Compounds shown are those included in Tier 3 pressure control evaluation.

TABLE A.3.4
PRESSURE GRADIENT MEASUREMENTS FROM ADDITIONAL LOCATIONS
ESTCP Tier 2 Vapor Screening Study
Building 103, Yorktown and Ranger, Jacksonville NAS, Jacksonville, FL

		Pressure Gradient (Pa)				
Condition	**Time**	**Window**	**SS-1**	**SS-2**	**SG-2-2.5 ft**	**SS-3**
Depressurization w/ fan on low	3/16/2009 17:00	-4.482	0	-0.747	-	-0.249
Depressurization w/ large fan on high	3/16/2009 17:00	-6.225	-0.498	-0.747	-	-0.498
Pressurization w/ large fan on high	3/18/2009 16:00	7.47	0.249	0.996	0.996	2.49

Note:

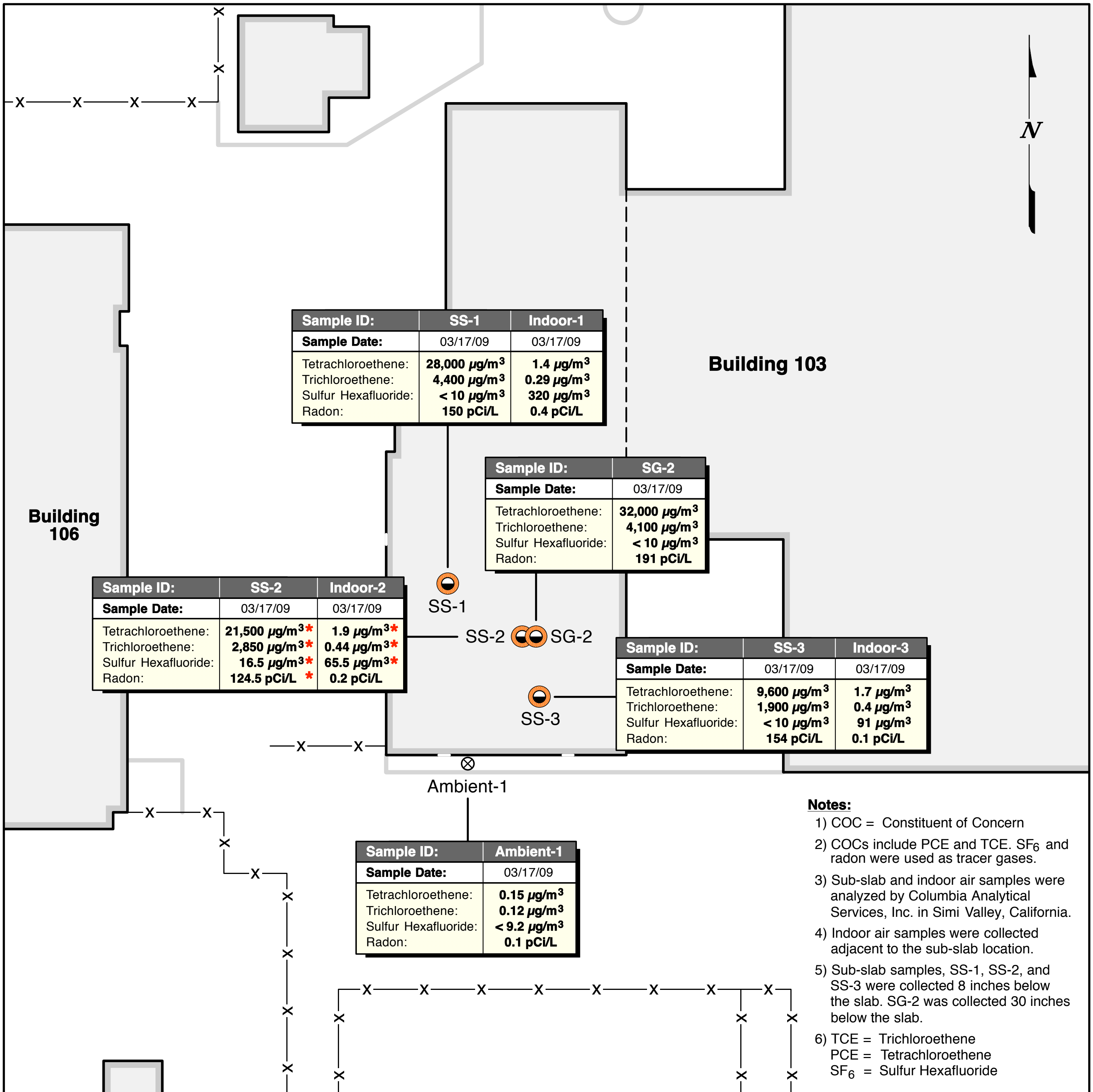
Hand recorded readings from pressure transducer.



SUB-SLAB, INDOOR AND AMBIENT AIR SAMPLING AND MEASUREMENT LOCATIONS

ESTCP Tier 2 Vapor Screening Study
Building 103, Jacksonville NAS, Florida

GSI Job No:	G-3213	Drawn By:	DLB
Issued:	18-Nov-11	Chk'd By:	DMB
Revised:	———	Appv'd By:	LMB
Scale:	As Shown		**FIGURE A.3.1**



SCALE (ft.)

0 25 50

LEGEND

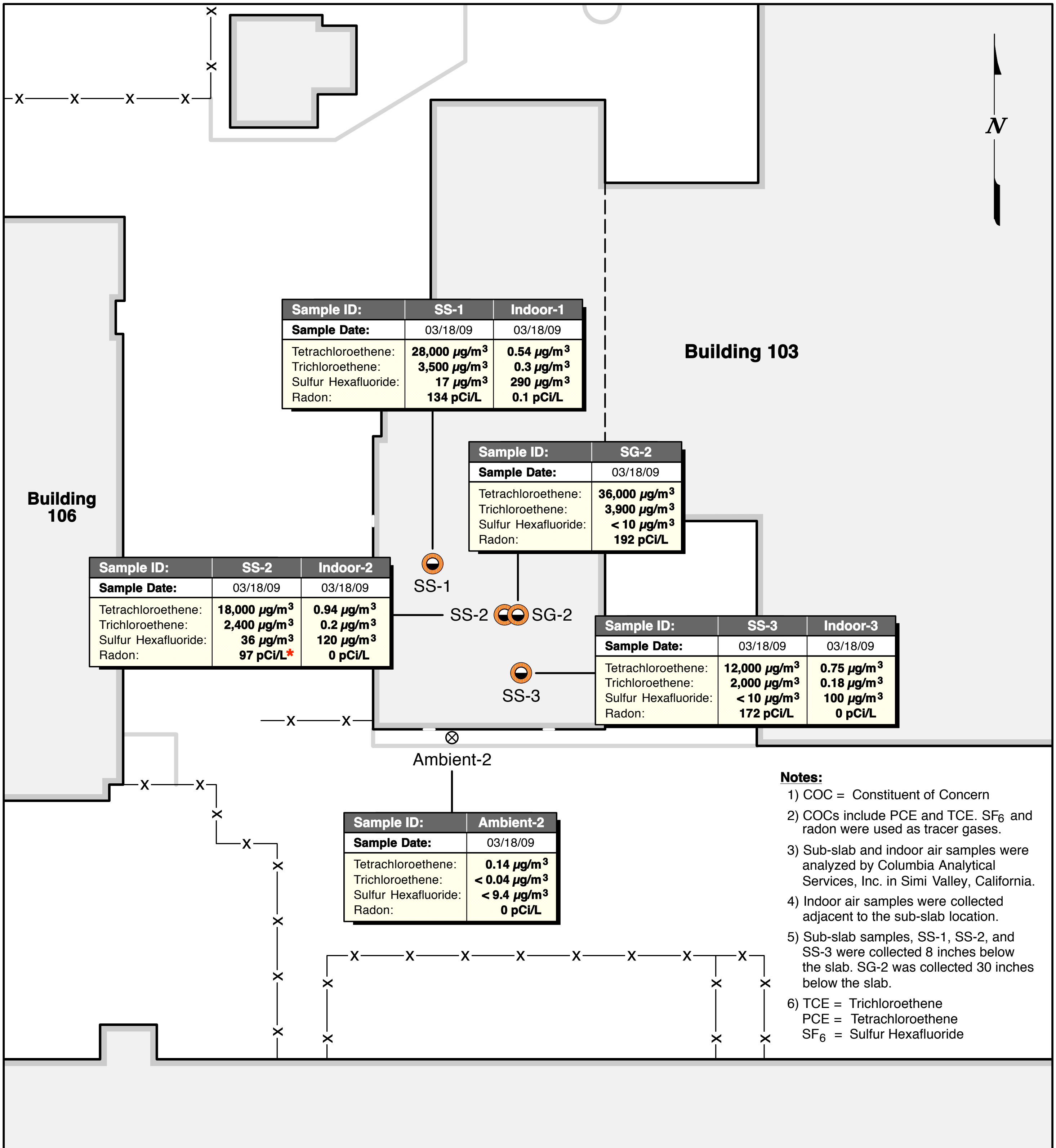
- Both sub-slab and pressure measurement point
- Ambient air sampling point
- One or more COCs detected above the reporting limit in the sub-slab and/or indoor air sample
- COCs not detected
- * Duplicate samples taken; average value shown
- Fence
- Road

GSI ENVIRONMENTAL

SUB-SLAB AND INDOOR AIR SAMPLING AND TESTING RESULTS: NEGATIVE PRESSURE

ESTCP Tier 2 Vapor Screening Study
Building 103, Jacksonville NAS, Florida

GSI Job No: G-3213		Drawn By: DLB	
Issued: 18-Nov-11		Chk'd By: DMB	
Revised: ———		Appv'd By: LMB	
Scale: As Shown		**FIGURE A.3.2**	



Sample ID:	SS-1	Indoor-1
Sample Date:	03/18/09	03/18/09
Tetrachloroethene:	28,000 μg/m^3	0.54 μg/m^3
Trichloroethene:	3,500 μg/m^3	0.3 μg/m^3
Sulfur Hexafluoride:	17 μg/m^3	290 μg/m^3
Radon:	134 pCi/L	0.1 pCi/L

Sample ID:	SG-2
Sample Date:	03/18/09
Tetrachloroethene:	36,000 μg/m^3
Trichloroethene:	3,900 μg/m^3
Sulfur Hexafluoride:	< 10 μg/m^3
Radon:	192 pCi/L

Sample ID:	SS-2	Indoor-2
Sample Date:	03/18/09	03/18/09
Tetrachloroethene:	18,000 μg/m^3	0.94 μg/m^3
Trichloroethene:	2,400 μg/m^3	0.2 μg/m^3
Sulfur Hexafluoride:	36 μg/m^3	120 μg/m^3
Radon:	97 pCi/L*	0 pCi/L

Sample ID:	SS-3	Indoor-3
Sample Date:	03/18/09	03/18/09
Tetrachloroethene:	12,000 μg/m^3	0.75 μg/m^3
Trichloroethene:	2,000 μg/m^3	0.18 μg/m^3
Sulfur Hexafluoride:	< 10 μg/m^3	100 μg/m^3
Radon:	172 pCi/L	0 pCi/L

Sample ID:	Ambient-2
Sample Date:	03/18/09
Tetrachloroethene:	0.14 μg/m^3
Trichloroethene:	< 0.04 μg/m^3
Sulfur Hexafluoride:	< 9.4 μg/m^3
Radon:	0 pCi/L

Notes:

1) COC = Constituent of Concern
2) COCs include PCE and TCE. SF_6 and radon were used as tracer gases.
3) Sub-slab and indoor air samples were analyzed by Columbia Analytical Services, Inc. in Simi Valley, California.
4) Indoor air samples were collected adjacent to the sub-slab location.
5) Sub-slab samples, SS-1, SS-2, and SS-3 were collected 8 inches below the slab. SG-2 was collected 30 inches below the slab.
6) TCE = Trichloroethene
PCE = Tetrachloroethene
SF_6 = Sulfur Hexafluoride

SCALE (ft.)
0 25 50

LEGEND

- Both sub-slab and pressure measurement point
- Ambient air sampling point
- One or more COCs detected above the reporting limit in the sub-slab and/or indoor air sample
- COCs not detected
- * Duplicate samples taken; average value shown
- Fence
- Road

GSI ENVIRONMENTAL

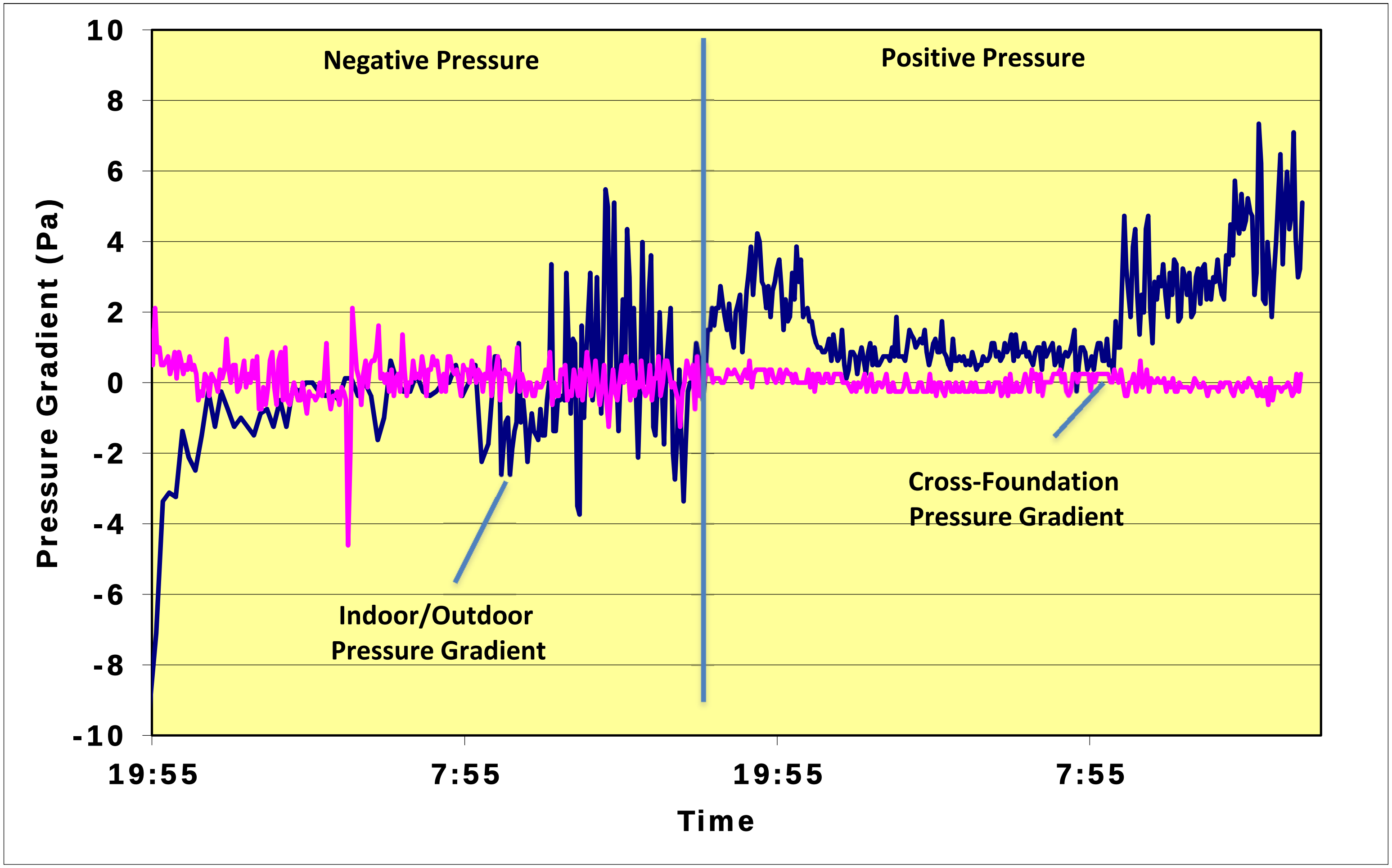
SUB-SLAB AND INDOOR AIR SAMPLING AND TESTING RESULTS: POSITIVE PRESSURE

ESTCP Tier 2 Vapor Screening Study
Building 103, Jacksonville NAS, Florida

GSI Job No: G-3213		Drawn By: DLB	
Issued: 18-Nov-11		Chk'd By: DMB	
Revised: ———		Appv'd By: LMB	
Scale: As Shown		**FIGURE A.3.3**	

GSI Job No. G-3213
Issued: 18 November 2011
Page 1 of 1

FIGURE A.3.4
BUILDING PRESSURE GRADIENTS
ESTCP Tier 2 Vapor Screening Study
Jacksonville Naval Air Station, Florida



Environmental Security Technology Certification Program
(ESTCP)

FINAL REPORT

Proposed Tier 2 Screening Criteria and Tier 3 Field Procedures for Evaluation of Vapor Intrusion
ESTCP Project ER-200707

Appendix A.4: Parris Island Marine Base, South Carolina

TABLES

FIGURES

GSI ENVIRONMENTAL

TABLE A.4.1
SAMPLING POINT COMPLETION DETAILS: SUB-SLAB AND PRESSURE MEASUREMENT
ESTCP Tier 2 Vapor Screening Study
Site 45 - Marine Corps Recruit Depot, Parris Island, SC

Well ID	Installed Total Depth (ft, bgs)	Boring Hole Diameter (inches)	Sand Backfill Filter Pack		Tubing Diameter (inches)
			U.S. Mesh Interval	Filter Pack Thickness (in)	
Sub-Slab Sampling Points					
SS-1	0.80	1	20/40	1	1/4
SS-2	0.80	1	20/40	1	1/4
SS-3	0.80	1	20/40	1	1/4
SG-2	2.0	1	20/40	1	1/4
Pressure Measurement Points					
SS-1-P	0.80	1	20/40	1	1/4
SS-2-P	0.80	1	20/40	1	1/4
SS-3-P	0.67	1	20/40	1	1/4
SG-2-P	2.0	1	20/40	1	1/4

Notes:
1. Locations are shown on Figure A.4.1.
2. All locations were completed to the surface with a bentonite seal.
3. bgs = Below ground surface.

GSI ENVIRONMENTAL

TABLE A.4.2
RESULTS OF SUB-SLAB ANALYSES: COMPOUNDS OF INTEREST
ESTCP Tier 2 Vapor Screening Study

Site 45 - Marine Corps Recruit Depot, Parris Island, SC

				DUPLICATE					
SAMPLE LOCATION:	SUBSLAB-NP-1	SUBSLAB-PP-1	SUBSLAB-NP-2	SUBSLAB-NP-2	SUBSLAB-PP-2	SUBSLAB-NP-3	SUBSLAB-PP-3	SG-2-2FT-NP	SG-2-2FT-PP
PRESSURE CONDITION:	Negative	Positive	Negative	Negative	Positive	Negative	Positive	Negative	Positive
SAMPLE DEPTH (ft bgs):	0.8	0.8	0.8	0.8	0.8	0.8	0.8	2	2
SAMPLE DATE:	6/30/2009	7/1/2009	6/30/2009	6/30/2009	7/1/2009	6/30/2009	7/1/2009	6/30/2009	7/1/2009
COMPOUND	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$
Volatile Organic Compounds (VOCs) by Method TO-15									
Benzene	**3.4**	**0.98**	**1**	**1.6**	**0.83**	**1.2**	<0.45	**0.93**	<0.46
Toluene	**5.6**	**2.4**	<2.3	**18**	<2.3	<2.3	<2.3	<2.2	<2.3
Tetrachloroethene	**190**	**74**	**240**	**120**	**160**	**89**	**91**	**190**	**170**
NIOSH 6602									
Sulfur Hexafluoride (SF6)	< 6.5	< 6.4	< 6.6	**10**	< 6.4	< 6.6	< 6.4	< 7.3	< 6.5
Radon									
Radon (pCi/L)	**2405**	**2073**	**2681**	**2752**	**2471**	**2372**	**2468**	**2728**	**2737**

Notes:

1. VOC and SF6 samples were analyzed by Columbia Analytical Services, Inc. in Simi Valley, California. Radon analysis by US(
2. Detected analytes are presented in **bold** type.
3. Compounds shown are those included in Tier 3 pressure control evaluation.

GSI ENVIRONMENTAL

TABLE A.4.3

RESULTS OF INDOOR AND AMBIENT AIR ANALYSES: COMPOUNDS OF INTEREST

ESTCP Tier 2 Vapor Screening Study

Site 45 - Marine Corps Recruit Depot, Parris Island, SC

				DUPLICATE					
SAMPLE LOCATION:	Indoor-NP-1	Indoor-NP-2	Indoor-NP-3	Indoor-NP-3	Ambient-1	Indoor-PP-1	Indoor-PP-2	Indoor-PP-3	Ambient-2
PRESSURE CONDITION:	Negative	Negative	Negative	Negative	Negative	Positive	Positive	Positive	Positive
SAMPLE DATE:	6/30/2009	6/30/2009	6/30/2009	6/30/2009	6/30/2009	7/1/2009	7/1/2009	7/1/2009	7/1/2009
COMPOUND	μg/m^3	μg/m^3	μg/m^3	μg/m^3	μg/m^3	μg/m^3	μg/m^3	μg/m^3	μg/m^3
Volatile Organic Compounds (VOCs) by Method TO-15 SIM									
Benzene	**0.41**	**0.49**	**0.43**	**0.42**	**0.46**	**0.71**	**0.68**	**0.69**	**0.84**
Toluene	**5.1**	**13**	**13**	**13**	**1.6**	**5.3**	**5.6**	**5.1**	**2.7**
Tetrachloroethene	**11**	**23**	**35**	**22**	**0.29**	**36**	**54**	**51**	**0.43**
NIOSH 6602									
Sulfur Hexafluoride (SF6)	**42**	**150**	**110**	**160**	< 10	**190**	**110**	**58**	< 9.1
Radon									
Radon (pCi/L)	**0.28**	**0.21**	**0.3**	**--**	**0.11**	**0.25**	**0.49**	**0.4**	**0.22**

Notes:
1. VOC and SF6 samples were analyzed by Columbia Analytical Services, Inc. in Simi Valley, California. Radon analysis by US(
2. Detected analytes are presented in **bold** type.
3. ND = compound was analyzed for, but not detected above the laboratory reporting limit
4. -- = not available
5. Compounds shown are those included in Tier 3 pressure control evaluation.

TABLE A.4.4
PRESSURE GRADIENT MEASUREMENTS FROM ADDITIONAL LOCATIONS
ESTCP Tier 2 Vapor Screening Study
Site 45 - Marine Corps Recruit Depot, Parris Island, SC

Condition	Pressure Gradient (Pa)					
	Time	Indoor/Outdoor	SS-1	SS-2	SG-2-2 ft	SS-3
Baseline Building Pressure	6/29/2009 13:00	-1.494	0	0	-0.996	-0.747
Depressurization w/ large fan on low	6/29/2009 13:00	-1.494	-0.498	0	-1.494	-0.747
Depressurization w/ large fan on high	6/29/2009 13:00	-2.49	-0.498	-0.249	-1.992	-1.494
Depressurization w/ building roof vents	6/29/2009 13:00	-24.9	-4.98	-1.743	0	-9.96

Note:

Hand recorded readings from pressure transducer.

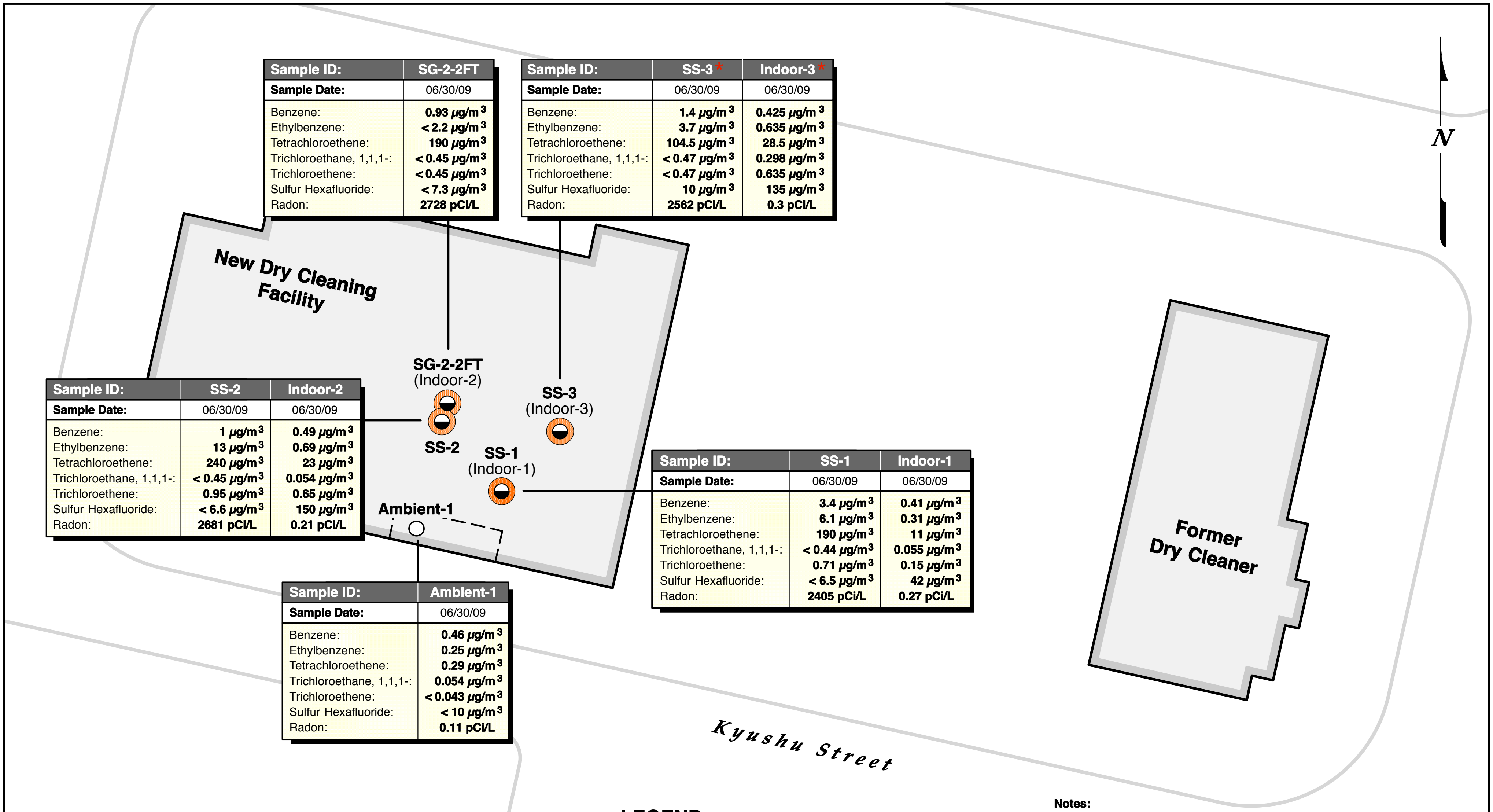
SCALE (ft.)
0 20 40

GSI ENVIRONMENTAL

GSI Job No.	G-3213	Drawn By:	DLB
Issued:	18-Nov-11	Chk'd By:	RCL
Revised:	————	Aprv'd By:	LMB
Scale:	As Shown		**FIGURE A.4.1**

SUB-SLAB, INDOOR AND AMBIENT AIR SAMPLING AND MEASUREMENT LOCATIONS

ESTCP Tier 2 Vapor Screening Study
Site 45, Marine Corps Recruit Depot, Parris Island, SC



Sample ID:	SG-2-2FT
Sample Date:	06/30/09
Benzene:	0.93 μg/m³
Ethylbenzene:	< 2.2 μg/m³
Tetrachloroethene:	190 μg/m³
Trichloroethane, 1,1,1-:	< 0.45 μg/m³
Trichloroethene:	< 0.45 μg/m³
Sulfur Hexafluoride:	< 7.3 μg/m³
Radon:	2728 pCi/L

Sample ID:	SS-3 *	Indoor-3 *
Sample Date:	06/30/09	06/30/09
Benzene:	1.4 μg/m³	0.425 μg/m³
Ethylbenzene:	3.7 μg/m³	0.635 μg/m³
Tetrachloroethene:	104.5 μg/m³	28.5 μg/m³
Trichloroethane, 1,1,1-:	< 0.47 μg/m³	0.298 μg/m³
Trichloroethene:	< 0.47 μg/m³	0.635 μg/m³
Sulfur Hexafluoride:	10 μg/m³	135 μg/m³
Radon:	2562 pCi/L	0.3 pCi/L

Sample ID:	SS-2	Indoor-2
Sample Date:	06/30/09	06/30/09
Benzene:	1 μg/m³	0.49 μg/m³
Ethylbenzene:	13 μg/m³	0.69 μg/m³
Tetrachloroethene:	240 μg/m³	23 μg/m³
Trichloroethane, 1,1,1-:	< 0.45 μg/m³	0.054 μg/m³
Trichloroethene:	0.95 μg/m³	0.65 μg/m³
Sulfur Hexafluoride:	< 6.6 μg/m³	150 μg/m³
Radon:	2681 pCi/L	0.21 pCi/L

Sample ID:	SS-1	Indoor-1
Sample Date:	06/30/09	06/30/09
Benzene:	3.4 μg/m³	0.41 μg/m³
Ethylbenzene:	6.1 μg/m³	0.31 μg/m³
Tetrachloroethene:	190 μg/m³	11 μg/m³
Trichloroethane, 1,1,1-:	< 0.44 μg/m³	0.055 μg/m³
Trichloroethene:	0.71 μg/m³	0.15 μg/m³
Sulfur Hexafluoride:	< 6.5 μg/m³	42 μg/m³
Radon:	2405 pCi/L	0.27 pCi/L

Sample ID:	Ambient-1
Sample Date:	06/30/09
Benzene:	0.46 μg/m³
Ethylbenzene:	0.25 μg/m³
Tetrachloroethene:	0.29 μg/m³
Trichloroethane, 1,1,1-:	0.054 μg/m³
Trichloroethene:	< 0.043 μg/m³
Sulfur Hexafluoride:	< 10 μg/m³
Radon:	0.11 pCi/L

LEGEND

- Both sub-slab and pressure measurement point
- One or more COCs detected above the reporting limit in the sub-slab and/or indoor air sample
- Ambient air sampling point
- * Duplicate samples taken; average value shown

Notes:

1) COC = Constituent of Concern
2) SF_6 and radon were used as tracer gases.
3) Sub-slab and indoor air samples were analyzed by Columbia Analytical Services, Inc. in Simi Valley, California.
4) Indoor air samples were collected adjacent to the sub-slab location.
5) Sub-slab samples, SS-1, SS-2, and SS-3 were collected 8 inches below the slab. SG-2 was collected 30 inches below the slab.
6) SF_6 = Sulfur Hexafluoride

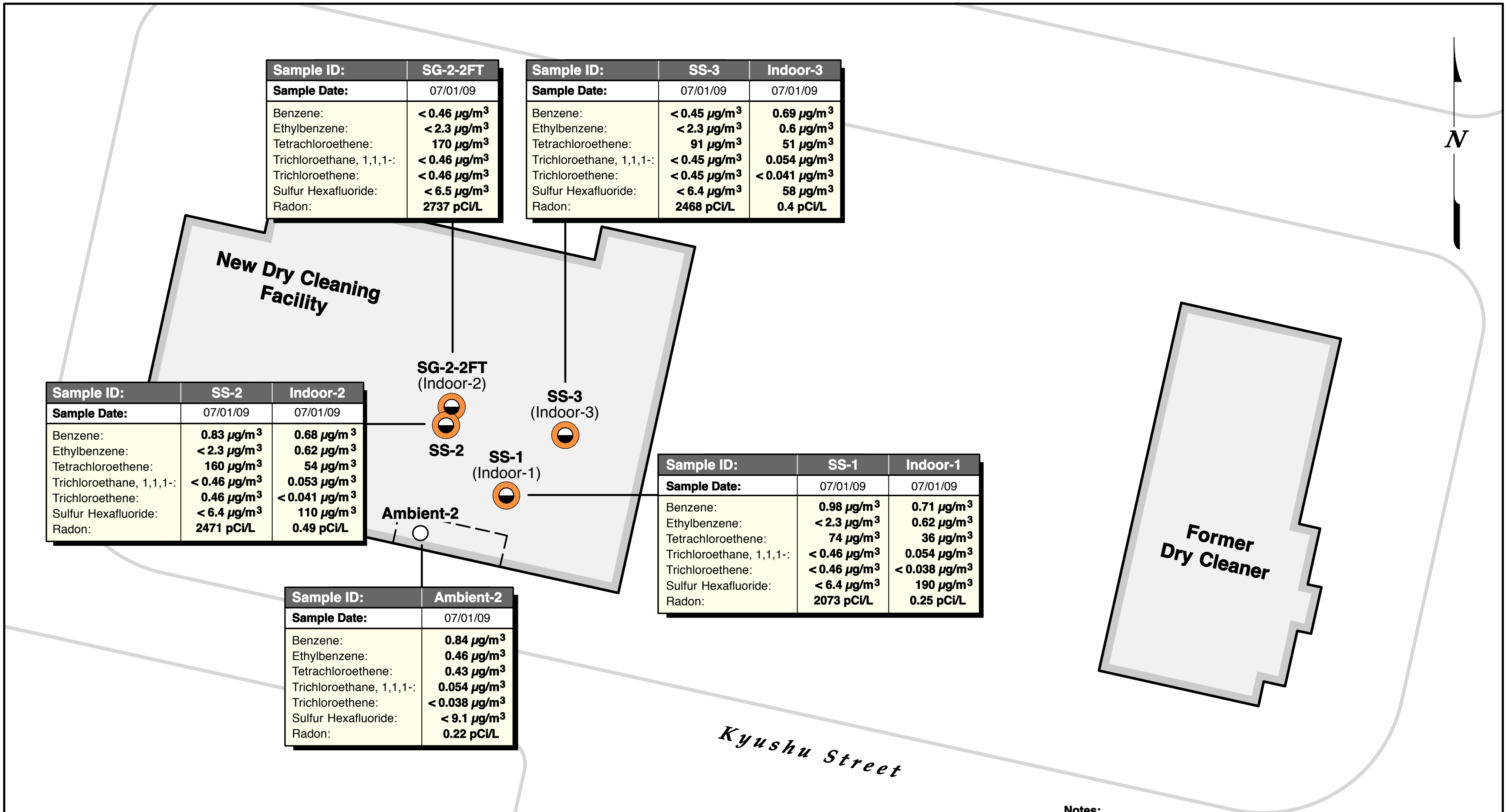
SCALE (ft.)
0 20 40

GSI ENVIRONMENTAL

GSI Job No.	G-3213	Drawn By:	DLB
Issued:	18-Nov-11	Chk'd By:	RCL
Revised:	________	Aprv'd By:	LMB
Scale:	As Shown		**FIGURE A.4.2**

SUB-SLAB AND INDOOR AIR SAMPLING AND TESTING RESULTS: NEGATIVE PRESSURE

ESTCP Tier 2 Vapor Screening Study
Site 45, Marine Corps Recruit Depot, Parris Island, SC



Sample ID:	SG-2-2FT
Sample Date:	07/01/09
Benzene:	< 0.46 $\mu g/m^3$
Ethylbenzene:	< 2.3 $\mu g/m^3$
Tetrachloroethene:	170 $\mu g/m^3$
Trichloroethane, 1,1,1-:	< 0.46 $\mu g/m^3$
Trichloroethene:	< 0.46 $\mu g/m^3$
Sulfur Hexafluoride:	< 6.5 $\mu g/m^3$
Radon:	2737 pCi/L

Sample ID:	SS-3	Indoor-3
Sample Date:	07/01/09	07/01/09
Benzene:	< 0.45 $\mu g/m^3$	0.69 $\mu g/m^3$
Ethylbenzene:	< 2.3 $\mu g/m^3$	0.6 $\mu g/m^3$
Tetrachloroethene:	91 $\mu g/m^3$	51 $\mu g/m^3$
Trichloroethane, 1,1,1-:	< 0.45 $\mu g/m^3$	0.054 $\mu g/m^3$
Trichloroethene:	< 0.45 $\mu g/m^3$	< 0.041 $\mu g/m^3$
Sulfur Hexafluoride:	< 6.4 $\mu g/m^3$	58 $\mu g/m^3$
Radon:	2468 pCi/L	0.4 pCi/L

Sample ID:	SS-2	Indoor-2
Sample Date:	07/01/09	07/01/09
Benzene:	0.83 $\mu g/m^3$	0.68 $\mu g/m^3$
Ethylbenzene:	< 2.3 $\mu g/m^3$	0.62 $\mu g/m^3$
Tetrachloroethene:	160 $\mu g/m^3$	54 $\mu g/m^3$
Trichloroethane, 1,1,1-:	< 0.46 $\mu g/m^3$	0.053 $\mu g/m^3$
Trichloroethene:	0.46 $\mu g/m^3$	< 0.041 $\mu g/m^3$
Sulfur Hexafluoride:	< 6.4 $\mu g/m^3$	110 $\mu g/m^3$
Radon:	2471 pCi/L	0.49 pCi/L

Sample ID:	SS-1	Indoor-1
Sample Date:	07/01/09	07/01/09
Benzene:	0.98 $\mu g/m^3$	0.71 $\mu g/m^3$
Ethylbenzene:	< 2.3 $\mu g/m^3$	0.62 $\mu g/m^3$
Tetrachloroethene:	74 $\mu g/m^3$	36 $\mu g/m^3$
Trichloroethane, 1,1,1-:	< 0.46 $\mu g/m^3$	0.054 $\mu g/m^3$
Trichloroethene:	< 0.46 $\mu g/m^3$	< 0.038 $\mu g/m^3$
Sulfur Hexafluoride:	< 6.4 $\mu g/m^3$	190 $\mu g/m^3$
Radon:	2073 pCi/L	0.25 pCi/L

Sample ID:	Ambient-2
Sample Date:	07/01/09
Benzene:	0.84 $\mu g/m^3$
Ethylbenzene:	0.46 $\mu g/m^3$
Tetrachloroethene:	0.43 $\mu g/m^3$
Trichloroethane, 1,1,1-:	0.054 $\mu g/m^3$
Trichloroethene:	< 0.038 $\mu g/m^3$
Sulfur Hexafluoride:	< 9.1 $\mu g/m^3$
Radon:	0.22 pCi/L

LEGEND

- Both sub-slab and pressure measurement point
- Ambient air sampling point
- One or more COCs detected above the reporting limit in the sub-slab and/or indoor air sample

Notes:

1) COC = Constituent of Concern
2) SF_6 and radon were used as tracer gases.
3) Sub-slab and indoor air samples were analyzed by Columbia Analytical Services, Inc. in Simi Valley, California.
4) Indoor air samples were collected adjacent to the sub-slab location.
5) Sub-slab samples, SS-1, SS-2, and SS-3 were collected 8 inches below the slab. SG-2 was collected 30 inches below the slab.
6) SF_6 = Sulfur Hexafluoride

SCALE (ft.)
0 20 40

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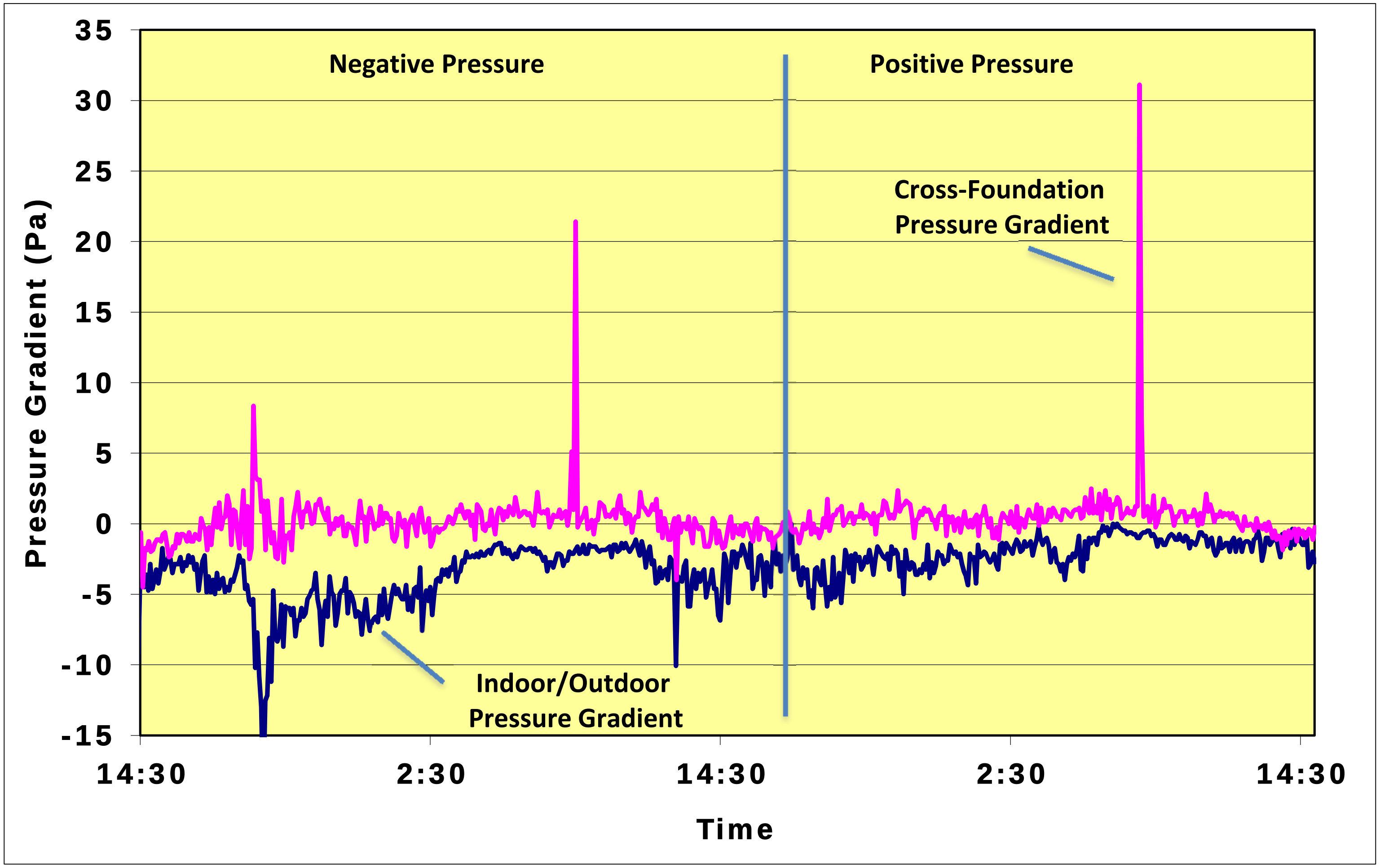
GSI Job No.	G-3213	Drawn By:	DLB
Issued:	18-Nov-11	Chk'd By:	RCL
Revised:	________	Aprv'd By:	LMB
Scale:	As Shown	FIGURE A.4.3	

SUB-SLAB AND INDOOR AIR SAMPLING AND TESTING RESULTS: POSITIVE PRESSURE

ESTCP Tier 2 Vapor Screening Study
Site 45, Marine Corps Recruit Depot, Parris Island, SC

FIGURE A.4.4
BUILDING PRESSURE GRADIENTS
ESTCP Tier 2 Vapor Screening Study
Site 45 - Marine Corps Recruit Depot, Parris Island, South Carolina



Environmental Security Technology Certification Program
(ESTCP)

FINAL REPORT

Proposed Tier 2 Screening Criteria and Tier 3 Field Procedures for Evaluation of Vapor Intrusion
ESTCP Project ER-200707

Appendix A.5: Tinker Air Force Base, Oklahoma City, Oklahoma

TABLES

FIGURES

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TABLE A.5.1
RESULTS OF GEOTECHNICAL ANALYSES
ESTCP Tier 2 Vapor Screening Study
Building 200, Tinker Air Force Base, Oklahoma City, OK

Sample ID	Sample Depth	Dry Bulk Density	Fraction Organic Carbon	Volumetric Water Content	Porosity		Intrinsic Permeability to Water	Native Hydraulic Conductivity
					Total	Air Filled	5 PSI Confining Stress	
Units	**ft**	**pcf**	**%**	**--**	**--**	**--**	**cm^2**	**cm/sec**
C1-PZ-2	1.5-2.5	111.2	3.2	0.323	0.336	0.014	1.7E-14	1.6E-09
C1-PZ-2	5.5-6.5	108	4.4	0.351	0.345	0.000	1.6E-14	1.6E-09
C1-PZ-2	9-10	NM	0.8	NM	NM	NM	NM	NM
C2-PZ-3	4-5	104.9	3.7	0.359	0.391	0.033	5.3E-14	5.2E-09
C2-PZ-3	7-8	119.7	0.4	0.278	0.273	0.000	5.8E-14	5.7E-09
C3-PZ-2	2-3	100.3	2.8	0.391	0.403	0.012	2.0E-14	2.0E-09
C3-PZ-2	6.5-7.5	106.4	2.2	0.3641	0.375	0.011	2.5E-14	2.4E-09
C3-PZ-2	10-11	110.9	0.4	0.2872	0.326	0.038	5.5E-12	5.4E-07

Notes:
1. Samples were analyzed by Fugro Consultants, Inc. in Houston, Texas
2. Dry bulk density determined by D 2166, Fraction Organic Carbon determined by D 2974, intrinsic permeability and hydraulic conductivi determined by D 5084, volumetric moisture content determined by D 2435, and total and air-filled porosity determined by D 65:
3. All sample orientations were vertical.
4. NM = No measurement; Sample ID C1-PZ-2 (9'-10') was fractured upon delivery to the laboratory, prohibiting the laboratory from analyzing for dry bulk density, volumetric water content, total or air filled porosity, intrinsic permeability, or native hydraulic conductivit

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TABLE A.5.2
SAMPLING POINT COMPLETION DETAILS: CLUSTERS
ESTCP Tier 2 Vapor Screening Study
Building 200, Tinker Air Force Base, Oklahoma City, OK

Well ID	Installed Total Depth (ft, bgs)	Screen Interval Depth (ft, bgs)	Screen Slot Size (--)	Boring Hole Diameter (inches)	Well Diameter (inches)	Sand Backfill Filter Pack		Tubing Diameter (inches)
						U.S. Mesh Interval	Filter Pack Thickness (ft)	
Cluster 1								
Groundwater Sampling Points								
C1-PZ-1	12.0	11.5-12	No. 010	7.75	1	20/40	1.5	N/A
C1-PZ-2	11.0	10.5-11	No. 010	2.25	1	20/40	1.5	N/A
C1-PZ-3	10.0	9.5-10	No. 010	7.75	1	20/40	1.5	N/A
C1-PZ-4	9.0	8.5-9	No. 010	2.25	1	20/40	1.5	N/A
C1-PZ-5	8.0	7.5-8	No. 010	2.25	1	20/40	1.5	N/A
Soil Gas Sampling Points								
C1-SG-1	9.0	N/A	N/A	2.25	N/A	20/40	0.5	1/8
C1-SG-2	8.0	N/A	N/A	2.25	N/A	20/40	0.5	1/8
C1-SG-3	6.0	N/A	N/A	2.25	N/A	20/40	0.5	1/8
C1-SG-4	4.0	N/A	N/A	2.25	N/A	20/40	0.5	1/8
C1-SG-5	2.0	N/A	N/A	2.25	N/A	20/40	0.5	1/8
Cluster 2								
Groundwater Sampling Points								
C2-PZ-1	14.0	13.5-14	No. 010	7.75	1	20/40	1.5	N/A
C2-PZ-2	13.0	12.5-13	No. 010	7.75	1	20/40	1.5	N/A
C2-PZ-3	12.0	11.5-12	No. 010	7.75	1	20/40	1.5	N/A
C2-PZ-4	10.0	9.5-10	No. 010	7.75	1	20/40	1.5	N/A
C2-PZ-5	9.0	8.5-9	No. 010	2.25	1	20/40	1.5	N/A
Soil Gas Sampling Points								
C2-SG-1	10.0	N/A	N/A	7.75	N/A	20/40	0.5	1/8
C2-SG-2	9.0	N/A	N/A	2.25	N/A	20/40	0.5	1/8
C2-SG-3	7.0	N/A	N/A	2.25	N/A	20/40	0.5	1/8
C2-SG-4	5.0	N/A	N/A	2.25	N/A	20/40	0.5	1/8
C2-SG-5	2.5	N/A	N/A	2.25	N/A	20/40	0.5	1/8

Continued on next page

TABLE A.5.2 (CONTINUED)

SAMPLING POINT COMPLETION DETAILS: CLUSTERS

ESTCP Tier 2 Vapor Screening Study

Building 200, Tinker Air Force Base, Oklahoma City, OK

Well ID	Installed Total Depth (ft, bgs)	Screen Interval Depth (ft, bgs)	Screen Slot Size (--)	Boring Hole Diameter (inches)	Well Diameter (inches)	Sand Backfill Filter Pack U.S. Mesh Interval	Sand Backfill Filter Pack Filter Pack Thickness (ft)	Tubing Diameter (inches)
Cluster 3								
Groundwater Sampling Points								
C3-PZ-1	15.0	14.5-15	No. 010	7.75	1	20/40	1.5	N/A
C3-PZ-2	13.0	12.5-13	No. 010	4	1	20/40	1.5	N/A
C3-PZ-3	11.0	10.5-11	No. 010	4	1	20/40	1.5	N/A
C3-PZ-4	10.0	9.5-10	No. 010	4	1	20/40	1.5	N/A
C3-PZ-5	9.0	8.5-9	No. 010	4	1	20/40	1.5	N/A
Soil Gas Sampling Points								
C3-SG-1	10.0	N/A	N/A	4	N/A	20/40	0.5	1/8
C3-SG-2	9.0	N/A	N/A	4	N/A	20/40	0.5	1/8
C3-SG-3	7.0	N/A	N/A	4	N/A	20/40	0.5	1/8
C3-SG-4	5.0	N/A	N/A	4	N/A	20/40	0.5	1/8
C3-SG-5	2.5	N/A	N/A	4	N/A	20/40	0.5	1/8

Notes:
1. Well locations are shown on Figure A.5.1
2. All locations were completed to the surface with a bentonite seal
3. bgs = Below ground surface.

TABLE A.5.3
DEPTH TO WATER MEASUREMENTS
ESTCP Tier 2 Vapor Screening Study
Building 200, Tinker Air Force Base, Oklahoma City, OK

Well ID	Installed Total Depth (ft, bgs)	Screen Interval Depth (ft, bgs)	Depth to Water (ft, bgs)	Measured Total Depth (ft, bgs)
Cluster 1				
C1-PZ-1	12.0	11.5-12	8.85	12.1
C1-PZ-2	11.0	10.5-11	8.5	10.6
C1-PZ-3	10.0	9.5-10	8.7	9.9
C1-PZ-4	9.0	8.5-9	DRY	9
C1-PZ-5	8.0	7.5-8	DRY	7.9
Cluster 2				
C2-PZ-1	14.0	13.5-14	10.1	13.85
C2-PZ-2	13.0	12.5-13	10.05	13.05
C2-PZ-3	12.0	11.5-12	9.95	12
C2-PZ-4	10.0	9.5-10	DRY	10
C2-PZ-5	9.0	8.5-9	DRY	9
Cluster 3				
C3-PZ-1	15.0	14.5-15	9.7	14.5
C3-PZ-2	13.0	12.5-13	9.6	13
C3-PZ-3	11.0	10.5-11	9.6	11
C3-PZ-4	10.0	9.5-10	9.45	10
C3-PZ-5	9.0	8.5-9	DRY	8.9

Notes:
1. Well locations are shown on Figure A.5.1
2. bgs = Below ground surface.

TABLE A.5.4
RESULTS OF GROUNDWATER ANALYSES: COMPOUNDS OF INTEREST
ESTCP Tier 2 Vapor Screening Study
Building 200, Tinker Air Force Base, Oklahoma City, Oklahoma

		DUPLICATE					
SAMPLE LOCATION:	C1-PZ-1	C1-PZ-1	C1-PZ-2	C1-PZ-3	C2-PZ-1	C2-PZ-2	C2-PZ-3
SCREEN INTERVAL (ft, bgs):	11.5-12	11.5-12	10.5-11	9.5-10	13.5-14	12.5-13	11.5-12
SAMPLE DATE:	9/3/2009	9/3/2009	9/3/2009	9/3/2009	9/3/2009	9/3/2009	9/3/2009
COMPOUND	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Volatile Organic Compounds (VOCs) by Method 8260B							
Dichloroethene, cis-1,2-	**0.0048**	**0.0048**	<0.00016	<0.00016	**0.89**	**0.51**	**0.089**
Dichloroethene, trans-1,2-	<0.00012	<0.00012	<0.00012	<0.00012	**0.011**	**0.0058**	**0.00093 J**
Tetrachloroethene	<0.00008	<0.00008	<0.00008	<0.00008	**0.0013**	**0.0005 J**	<0.00008
Trichloroethene	<0.00013	< 0.003 **B**	<0.00013	< 0.003 **B**	**1.3 H**	**0.7 H**	**0.11 H**
Vinyl chloride	<0.00013	**0.00091 J,H**	<0.00013	<0.00013	**0.2**	**0.098**	**0.016 H**

SAMPLE LOCATION:	C3-PZ-1	C3-PZ-2	C3-PZ-3	C3-PZ-4	Field Blank	Trip Blank
SCREEN INTERVAL (ft, bgs):	14.5-15	12.5-13	10.5-11	9.5-10	NA	NA
SAMPLE DATE:	9/3/2009	9/3/2009	9/3/2009	9/3/2009	9/3/2009	NA
COMPOUND	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Volatile Organic Compounds (VOCs) by Method 8260B						
Dichloroethene, cis-1,2-	**0.21 H**	**0.06**	**0.025**	**0.013**	<0.00016	<0.00016
Dichloroethene, trans-1,2-	**0.0062**	**0.0021**	**0.00056 J**	<0.00012	<0.00012	<0.00012
Tetrachloroethene	<0.00008	<0.00008	<0.00008	<0.00008	<0.00008	<0.00008
Trichloroethene	**0.0063 H**	< 0.003 **B**	< 0.003 **B**	< 0.003 **B**	**0.0006 J,H**	< 0.003 **B**
Vinyl chloride	**0.033 H**	**0.0079 H**	**0.0015 J,H**	**0.00058 J,H**	<0.00013	<0.00013

Notes:

1. Sampling locations are shown on Figure A.5.1.
2. Samples were analyzed by TestAmerica Laboratories, Inc. in Houston, Texas by Method 8260B.
3. Detected analytes are presented in **bold** type.
4. < = Not detected at detection limit shown.

J = Result is less than the reporting limit but greater than or equal to the Method Detection Limit and the concentration is an approximate value.

B = Detection Limit has been recalculated based on detections on blank samples, as in EPA540/R-99/008

H = Bias in sampling result likely to be high

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TABLE A.5.5
RESULTS OF SOIL GAS ANALYSES: COMPOUNDS OF INTEREST
ESTCP Tier 2 Vapor Screening Study
Building 200, Tinker Air Force Base, Oklahoma City, OK

SAMPLE LOCATION:	C1-SG-2	C1-SG-4	C1-SG-5	C2-SG-3	C2-SG-4	C2-SG-5	C3-SG-2
SCREEN INTERVAL (ft, bgs):	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SAMPLE DATE:	9/3/2009	9/3/2009	9/3/2009	9/3/2009	9/3/2009	9/3/2009	9/4/2009
SAMPLE COLLECTION METHOD:	Syringe/Tedlar	Syringe/Tedlar	Syringe/Tedlar	Syringe/Tedlar	Syringe/Tedlar	Syringe/Tedlar	Summa Can
COMPOUND	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$
Volatile Organic Compounds (VOCs) by Method TO-15							
Dichloroethene, cis-1,2-	< 25	< 25	< 10	< 5	< 10	< 5	**320**
Dichloroethene, trans-1,2-	< 25	< 25	< 10	< 5	< 10	< 5	**6.3**
Tetrachloroethene	< 25	< 25	< 10	< 10	< 5	< 10	< 5
Trichloroethene	< 25	< 25	< 10	< 10	< 5	< 10	< 5
Vinyl Chloride	< 25	< 25	< 10	< 5	< 10	< 5	**9.8**
NIOSH 6602							
Sulfur Hexafluoride (SF6)	**23**	**420**	**49**	**2,700**	**150,000,000**	**9,300**	**580,000**

			DUPLICATE	
SAMPLE LOCATION:	C3-SG-3	C3-SG-4	C3-SG-4	C3-SG-5
SCREEN INTERVAL (ft, bgs):	N/A	N/A	N/A	N/A
SAMPLE DATE:	9/4/2009	9/3/2009	9/3/2009	9/4/2009
SAMPLE COLLECTION METHOD:	Summa Can	Syringe/Tedlar	Syringe/Tedlar	Summa Can
COMPOUND	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$
Volatile Organic Compounds (VOCs) by Method TO-15				
Dichloroethene, cis-1,2-	**100**	< 10	< 10	< 4.9
Dichloroethene, trans-1,2-	< 4.3	< 10	< 10	< 4.9
Tetrachloroethene	< 3.6	< 4.3	< 10	< 4.9
Trichloroethene	< 3.6	< 4.3	< 10	< 4.9
Vinyl Chloride	< 4.3	< 10	< 10	< 4.9
NIOSH 6602				
Sulfur Hexafluoride (SF6)	**260,000**	**100**	**190**	**1,500,000**

Notes:

1. Sampling locations are shown on Figure A.5.1.
2. Samples were analyzed by Columbia Analytical Services, Inc. in Simi Valley, California.
3. Analytes shown are those detected in groundwater, plus sulfur hexafluoride. Detected analytes are presented in **bold** type.
4. < = Not detected at detection limit shown.

TABLE A.5.6
RESULTS OF SOIL PERMEABILITY TESTING
ESTCP Tier 2 Vapor Screening Study
Building 200, Tinker Air Force Base, Oklahoma City, OK

Cluster Location	Sample Point	Air Flow Rate (Q) (L/min)	Air Flow Rate (Q) (cc/min)	Vacuum (P) (in. Hg)	Vacuum (P) (in. H2O)	Slope of Q vs. P	Permeability (cm2)
Cluster 1	PZ-5	0.35	350	0.1	2	625	1.10E-10
		1	1000	0.2	3		
		3	3000	0.3	4		
		4	4000	0.4	5.5		
		6	6000	0.6	8		
		7	7000	0.7	10		
		8	8000	0.9	12		
		12	12000	1.5	21		
		10	10000	1.1	15		
		14	14000	1.6	22		
	PZ-4	0.2	200	0.4	6	247	4.33E-11
		0.6	600	0.5	7		
		0.9	900	0.6	8		
		1.5	1500	0.7	9.5		
		2	2000	0.8	11.5		
		3	3000	1.1	15.5		
		3.5	3500	1.2	17		
		4	4000	1.6	22		
Cluster 2	PZ-5	0.1	100	0.9	12.5	54	9.46E-12
		0.2	200	1.2	16		
		0.4	400	1.6	22		
		0.6	600	1.8	25		
		0.8	800	1.9	26.5		
		1	1000	2.1	28		
Cluster 3	PZ-5	0.8	800	0.2	3.2	645	1.13E-10
		2	2000	0.3	3.6		
		6	6000	0.3	4.2		
		8	8000	0.4	5		
		10	10000	1.2	16		
		12	12000	1.3	18		
		16	16000	1.5	20		

Parameter	Symbol	Value	Units	Basis
Viscosity of air	viscosity	1.73E-04	g/cm-s (poise)	Literature (40 deg. F)
Length: Mont. Well	L	15.2	cm	Screen length for monitoring well points (6 inches)
Diameter: Mont. Well	D	3.2	cm	Inside diameter for monitoring well points
Units Conversion		1.07E-06		From calculation methods sheet
L/D Term: Well Pt		0.0009		Calculated

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TABLE A.5.7
SAMPLING POINT COMPLETION DETAILS: SUB-SLAB AND PRESSURE MEASUREMENT
ESTCP Tier 2 Vapor Screening Study
Building 200, Tinker Air Force Base, Oklahoma City, OK

Well ID	Installed Total Depth (ft, bgs)	Boring Hole Diameter (inches)	Sand Backfill Filter Pack		Tubing Diameter (inches)
			U.S. Mesh Interval	Filter Pack Thickness (in)	
Sub-Slab Sampling Points					
SubSlab-1	0.70	1	20/40	1	1/8
SubSlab-2	0.70	1	20/40	1	1/8
SubSlab-3	0.70	1	20/40	1	1/8
SG-2-2.5ft	2.5	1	20/40	1	1/4
Pressure Measurement Points					
SubSlab-1-P	0.70	1	20/40	1	1/4
SubSlab-2-P	0.70	1	20/40	1	1/4
SubSlab-3-P	0.70	1	20/40	1	1/4
SG-2-2.5ft-P	2.5	1	20/40	1	1/4

Notes:
1. Locations are shown on Figure A.5.6
2. All locations were completed to the surface with a bentonite seal
3. bgs = Below ground surface.

TABLE A.5.8
RESULTS OF SUB-SLAB ANALYSES: COMPOUNDS OF INTEREST
ESTCP Tier 2 Vapor Screening Study
Building 200, Tinker Air Force Base, Oklahoma City, OK

				DUPLICATE					
SAMPLE LOCATION:	SubSlab-1	SubSlab-1	SubSlab-2	SubSlab-2	SubSlab-2	SubSlab-3	SubSlab-3	SG-2-2.5ft	SG-2-2.5ft
PRESSURE CONDITION:	Negative	Positive	Negative	Negative	Positive	Negative	Positive	Negative	Positive
SAMPLE DEPTH (ft bgs):	0.70	0.70	0.70	0.70	0.70	0.70	0.70	2.50	2.50
SAMPLE DATE:	9/1/2009	9/2/2009	9/1/2009	9/1/2009	9/2/2009	9/1/2009	9/2/2009	9/1/2009	9/2/2009
COMPOUND	µg/m^3	µg/m^3	µg/m^3	µg/m^3	µg/m^3	µg/m^3	µg/m^3	µg/m^3	µg/m^3
Volatile Organic Compounds (VOCs) by Method TO-15									
Benzene	**1.0**	**2.2**	**1**	**0.77**	**0.88**	**28**	**9.4**	<0.46	**0.77**
Toluene	**7.8**	**11**	**12**	**7.8**	**5.7**	**34**	**11**	**5.4**	**3.2**
Dichloroethene, cis-1,2-	**2.7**	< 0.45	< 0.44	< 0.45	< 0.44	< 0.44	< 0.44	< 0.46	< 0.45
Dichloroethene, trans-1, 2-	< 0.45	< 0.45	< 0.44	< 0.45	< 0.44	< 0.44	< 0.44	< 0.46	< 0.45
Tetrachloroethene	**18**	**3.9**	**31**	**29**	**11**	**80**	**63**	**31**	**2.9**
Trichloroethene	**22**	**1.3**	**1.9**	**1.7**	< 0.44	< 0.44	< 0.44	**0.89**	< 0.45
Vinyl Chloride	< 0.45	< 0.45	< 0.44	< 0.45	< 0.44	< 0.44	< 0.44	< 0.46	< 0.45
Radon									
Radon (pCi/L)	**13.5**	**1.1**	**69.8**	**71.4**	**5.8**	**175.0**	**102.6**	**125.7**	**8.2***

Notes:
1. VOC samples were analyzed by Columbia Analytical Services, Inc. in Simi Valley, California. Radon analysis by USC. Sulfur hexafluoride not analyzed due to cylinder shipping err
2. Detected analytes are presented in **bold** type.
3. < = not detected at detection limit shown.
4. * = Average value between actual sample and its duplicate
5. Compounds shown include those i) detected in groundwater samples collected for Tier 2 or ii) evaluated in Tier 3 pressure control demonstration.

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TABLE A.5.9

RESULTS OF INDOOR AND AMBIENT AIR ANALYSES: COMPOUNDS OF INTEREST

ESTCP Tier 2 Vapor Screening Study

Building 200, Tinker Air Force Base, Oklahoma City, OK

SAMPLE LOCATION:	Indoor-1	Indoor-1	Indoor-2	Indoor-2	*DUPLICATE* Indoor-2	Indoor-3	Indoor-3	Ambient-1	Ambient-1A	Ambient-2	Ambient-2A
PRESSURE CONDITION:	Negative	Positive	Negative	Positive	Positive	Negative	Positive	Negative	Negative	Positive	Positive
SAMPLE DATE:	9/1/2009	9/2/2009	9/1/2009	9/2/2009	9/2/2009	9/1/2009	9/2/2009	9/1/2009	9/1/2009	9/2/2009	9/2/2009
COMPOUND	μg/m^3	μg/m^3	μg/m^3	μg/m^3	μg/m^3	μg/m^3	μg/m^3	μg/m^3	μg/m^3	μg/m^3	μg/m^3
Volatile Organic Compounds (VOCs) by Method TO-15 SIM											
Benzene	**0.83**	**0.41**	**0.56**	**0.39**	**0.4**	**0.58**	**0.4**	**0.49**	**0.66**	**0.42**	**0.56**
Toluene	**6.7**	**0.55**	**5.3**	**0.62**	**0.71**	**5.6**	**0.56**	**0.81**	**8.5**	**0.6**	**1.7**
Dichloroethene, cis-1,2-	<0.032	< 0.034	<0.038	< 0.037	< 0.041	< 0.037	< 0.041	< 0.036	< 0.034	< 0.038	< 0.04
Dichloroethene, trans-1,2-	<0.032	< 0.034	**0.041**	< 0.037	< 0.04	**0.047**	< 0.037	< 0.041	**0.076**	< 0.034	< 0.038
Tetrachloroethene	**1.5**	**0.27**	**6.2**	**0.51**	**0.22**	**6.5**	**0.39**	**6.6**	**5.9**	**0.37**	**1.2**
Trichloroethene	**0.042**	< 0.034	**0.044**	< 0.037	< 0.04	**0.044**	< 0.037	< 0.041	< 0.036	< 0.034	< 0.038
Vinyl Chloride	< 0.032	< 0.034	< 0.038	< 0.037	<0.041	< 0.037	< 0.041	< 0.036	< 0.034	< 0.038	< 0.04
Radon (pCi/L)	**0.3**	**0.2**	**0.2**	**0.2**	--	**0.3**	**0.2**	**0.2**	**0.2**	**0.3**	**0.2**

Notes:

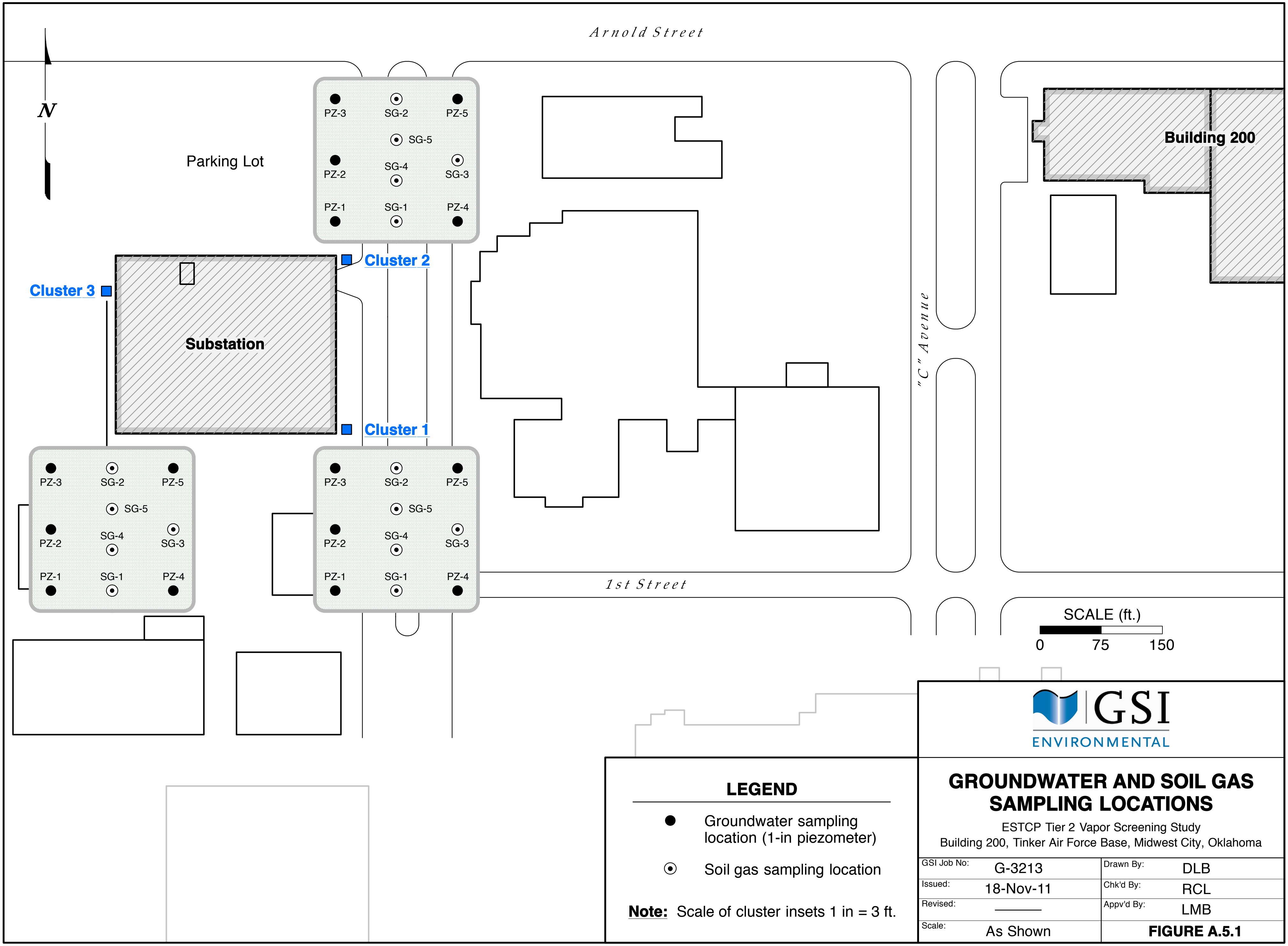
1. VOC samples were analyzed by Columbia Analytical Services, Inc. in Simi Valley, California. Radon analysis by USC. Sulfur hexafluoride not analyzed due to cylinder shipping err
2. Detected analytes are presented in **bold** type.
3. < = not detected at detection limit shown.
4. -- = not available
5. Compounds shown include those i) detected in groundwater samples collected for Tier 2 or ii) evaluated in Tier 3 pressure control demonstration.

TABLE A.5.10
PRESSURE GRADIENT MEASUREMENTS FROM ADDITIONAL LOCATIONS
ESTCP Tier 2 Vapor Screening Study
Building 200, Tinker Air Force Base, Oklahoma City, OK

	Pressure Gradient (in H2O)						
Condition	**Time**	**Indoor/Outdoor**	**Indoor/Building**	**SS-1**	**SS-2**	**SG-2-2 ft**	**SS-3**
Baseline Building Pressure	6/29/2009 13:00	0	0	0	0	0	0
Depressurization w/ large fan on low	6/29/2009 13:00	15.438	9.711	3.735	4.233	4.233	4.482

Note:

Hand recorded readings from pressure transducer.



GSI ENVIRONMENTAL

LEGEND

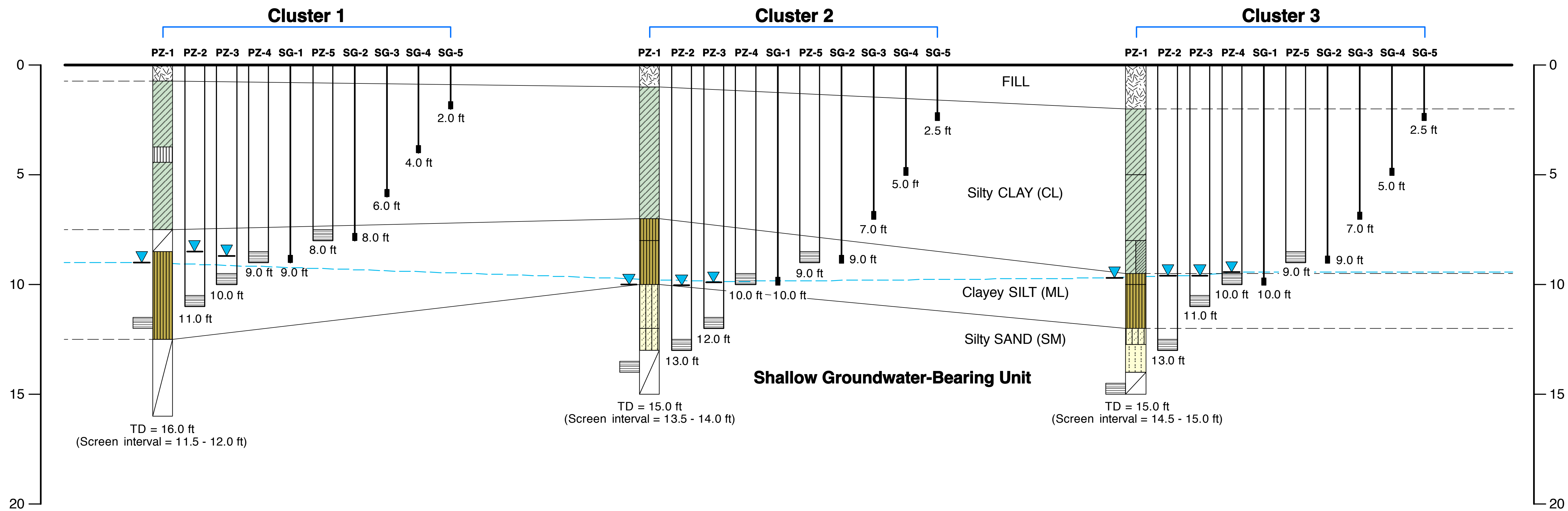
- ● Groundwater sampling location (1-in piezometer)
- ⊙ Soil gas sampling location

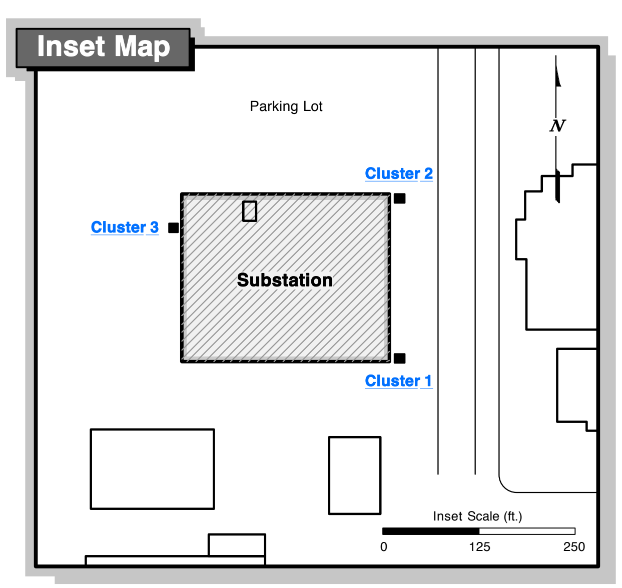
Note: Scale of cluster insets 1 in = 3 ft.

GROUNDWATER AND SOIL GAS SAMPLING LOCATIONS

ESTCP Tier 2 Vapor Screening Study
Building 200, Tinker Air Force Base, Midwest City, Oklahoma

GSI Job No:	G-3213	Drawn By:	DLB
Issued:	18-Nov-11	Chk'd By:	RCL
Revised:	———	Appv'd By:	LMB
Scale:	As Shown		**FIGURE A.5.1**





LEGEND

- FILL
- CLAY (CH)
- Silty CLAY (CL)
- SAND (SP)
- Silty SAND (SM)
- Clayey SILT (ML)
- No Recovery
- Screen interval
- Static water level, as measured on 9-Feb-09
- Potentiometric surface based on static water levels measured on 01-Sept-09

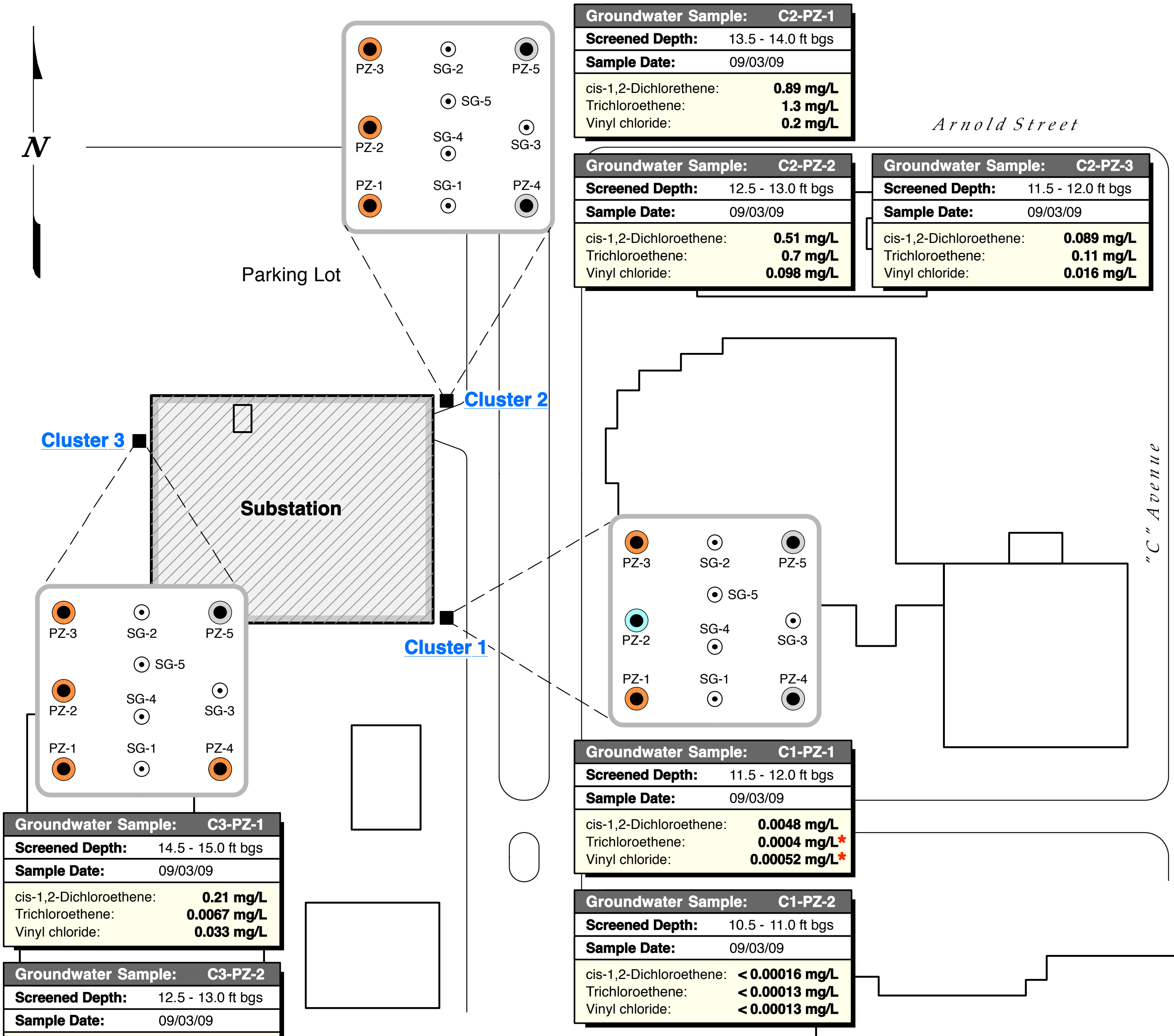
Note: To illustrate the entire lithology at C1-PZ-1, C2-PZ-1, and C3-PZ-1, the screen interval is presented adjacent to the lithology.

GSI ENVIRONMENTAL

CONCEPTUAL CROSS-SECTION OF SUBSURFACE SAMPLE POINTS AND SHALLOW GEOLOGY

ESTCP Tier 2 Vapor Screening Study
Building 200, Tinker Air Force Base, Midwest City, Oklahoma

GSI Job No:	G-3213	Drawn By:	DLB
Issued:	18-Nov-11	Chk'd By:	RCL
Revised:	———	Appv'd By:	LMB
Scale:	As Shown		**FIGURE A.5.2**



Groundwater Sample:	C2-PZ-1
Screened Depth:	13.5 - 14.0 ft bgs
Sample Date:	09/03/09
cis-1,2-Dichloroethene:	0.89 mg/L
Trichloroethene:	1.3 mg/L
Vinyl chloride:	0.2 mg/L

Groundwater Sample:	C2-PZ-2
Screened Depth:	12.5 - 13.0 ft bgs
Sample Date:	09/03/09
cis-1,2-Dichloroethene:	0.51 mg/L
Trichloroethene:	0.7 mg/L
Vinyl chloride:	0.098 mg/L

Groundwater Sample:	C2-PZ-3
Screened Depth:	11.5 - 12.0 ft bgs
Sample Date:	09/03/09
cis-1,2-Dichloroethene:	0.089 mg/L
Trichloroethene:	0.11 mg/L
Vinyl chloride:	0.016 mg/L

Groundwater Sample:	C1-PZ-1
Screened Depth:	11.5 - 12.0 ft bgs
Sample Date:	09/03/09
cis-1,2-Dichloroethene:	0.0048 mg/L
Trichloroethene:	0.0004 mg/L*
Vinyl chloride:	0.00052 mg/L*

Groundwater Sample:	C1-PZ-2
Screened Depth:	10.5 - 11.0 ft bgs
Sample Date:	09/03/09
cis-1,2-Dichloroethene:	< 0.00016 mg/L
Trichloroethene:	< 0.00013 mg/L
Vinyl chloride:	< 0.00013 mg/L

Groundwater Sample:	C1-PZ-3
Screened Depth:	9.5 - 10.0 ft bgs
Sample Date:	09/03/09
cis-1,2-Dichloroethene:	< 0.00016 mg/L
Trichloroethene:	0.00093 J mg/L
Vinyl chloride:	< 0.00013 mg/L

Groundwater Sample:	C3-PZ-1
Screened Depth:	14.5 - 15.0 ft bgs
Sample Date:	09/03/09
cis-1,2-Dichloroethene:	0.21 mg/L
Trichloroethene:	0.0067 mg/L
Vinyl chloride:	0.033 mg/L

Groundwater Sample:	C3-PZ-2
Screened Depth:	12.5 - 13.0 ft bgs
Sample Date:	09/03/09
cis-1,2-Dichloroethene:	0.06 mg/L
Trichloroethene:	0.0023 mg/L
Vinyl chloride:	0.0079 mg/L

Groundwater Sample:	C3-PZ-3
Screened Depth:	10.5 - 11.0 ft bgs
Sample Date:	09/03/09
cis-1,2-Dichloroethene:	0.025 mg/L
Trichloroethene:	0.00086 J mg/L
Vinyl chloride:	0.0015 J mg/L

Groundwater Sample:	C3-PZ-4
Screened Depth:	9.5 - 15.0 ft bgs
Sample Date:	09/03/09
cis-1,2-Dichloroethene:	0.013 mg/L
Trichloroethene:	0.00076 J mg/L
Vinyl chloride:	0.00058 J mg/L

LEGEND

- ● Groundwater sampling location (1-in piezometer)
- ⊙ Soil gas sampling location
- One or more COCs detected above the reporting limit
- COCs not detected
- Sample not collected
- * Duplicate samples taken; average value shown

Notes:

1) COC = Constituent of Concern (i.e., VC, TCE, and 1,2-DCE)

2) bgs = Below ground surface

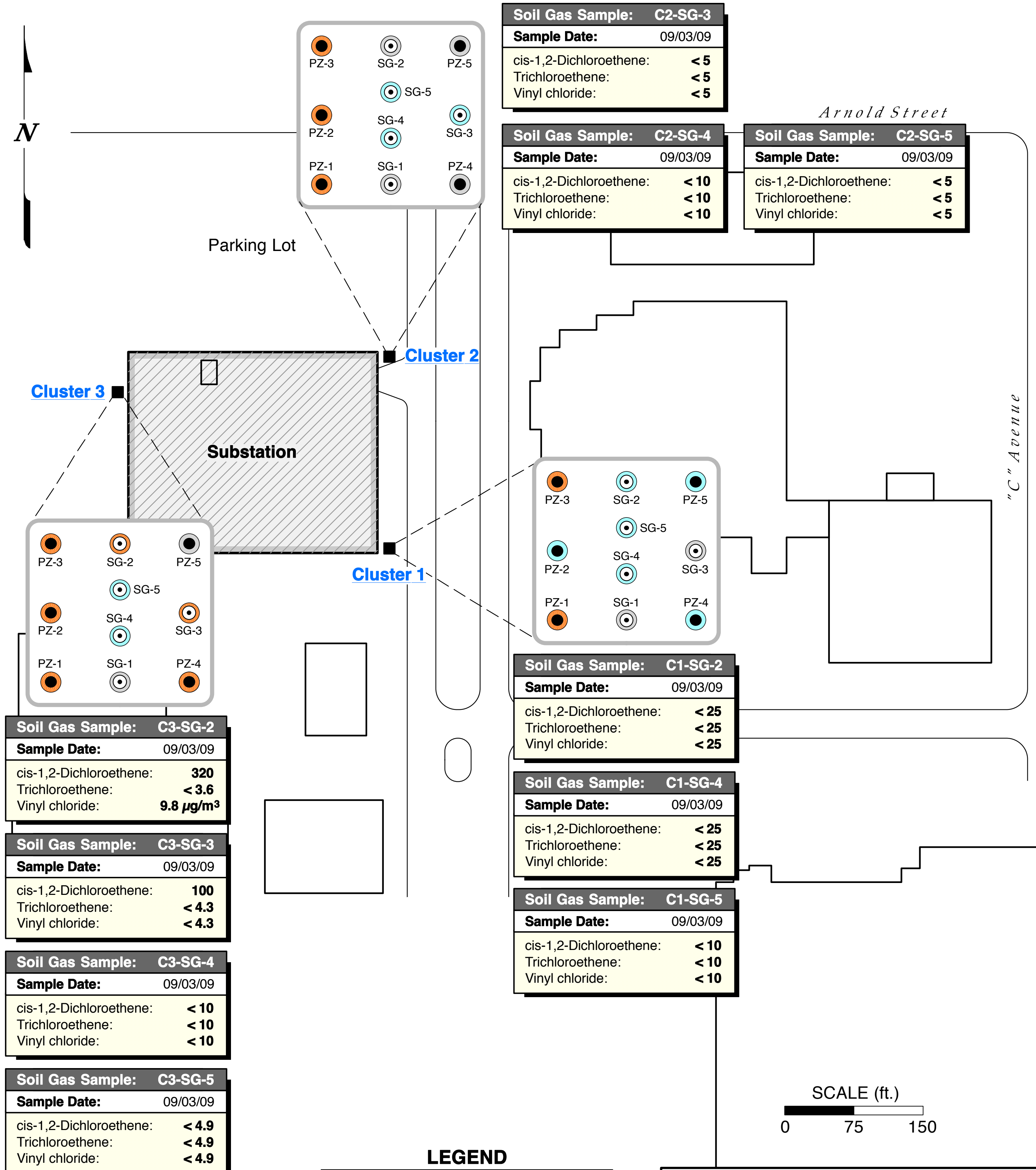
3) Scale of cluster insets 1in = 3 ft.

GSI ENVIRONMENTAL

GROUNDWATER SAMPLING AND TESTING RESULTS

ESTCP Tier 2 Vapor Screening Study
Building 200, Tinker Air Force Base, Midwest City, Oklahoma

GSI Job No: G-3213		Drawn By: DLB	
Issued: 18-Nov-11		Chk'd By: RCL	
Revised: ——		Appv'd By: LMB	
Scale: As Shown		FIGURE A.5.3	



Soil Gas Sample:	C2-SG-3
Sample Date:	09/03/09
cis-1,2-Dichloroethene:	**< 5**
Trichloroethene:	**< 5**
Vinyl chloride:	**< 5**

Soil Gas Sample:	C2-SG-4
Sample Date:	09/03/09
cis-1,2-Dichloroethene:	**< 10**
Trichloroethene:	**< 10**
Vinyl chloride:	**< 10**

Soil Gas Sample:	C2-SG-5
Sample Date:	09/03/09
cis-1,2-Dichloroethene:	**< 5**
Trichloroethene:	**< 5**
Vinyl chloride:	**< 5**

Soil Gas Sample:	C3-SG-2
Sample Date:	09/03/09
cis-1,2-Dichloroethene:	**320**
Trichloroethene:	**< 3.6**
Vinyl chloride:	**9.8 μg/m³**

Soil Gas Sample:	C3-SG-3
Sample Date:	09/03/09
cis-1,2-Dichloroethene:	**100**
Trichloroethene:	**< 4.3**
Vinyl chloride:	**< 4.3**

Soil Gas Sample:	C3-SG-4
Sample Date:	09/03/09
cis-1,2-Dichloroethene:	**< 10**
Trichloroethene:	**< 10**
Vinyl chloride:	**< 10**

Soil Gas Sample:	C3-SG-5
Sample Date:	09/03/09
cis-1,2-Dichloroethene:	**< 4.9**
Trichloroethene:	**< 4.9**
Vinyl chloride:	**< 4.9**

Soil Gas Sample:	C1-SG-2
Sample Date:	09/03/09
cis-1,2-Dichloroethene:	**< 25**
Trichloroethene:	**< 25**
Vinyl chloride:	**< 25**

Soil Gas Sample:	C1-SG-4
Sample Date:	09/03/09
cis-1,2-Dichloroethene:	**< 25**
Trichloroethene:	**< 25**
Vinyl chloride:	**< 25**

Soil Gas Sample:	C1-SG-5
Sample Date:	09/03/09
cis-1,2-Dichloroethene:	**< 10**
Trichloroethene:	**< 10**
Vinyl chloride:	**< 10**

LEGEND

- Groundwater sampling location (1-in piezometer)
- Soil gas sampling location
- One or more COCs detected above the reporting limit
- COCs not detected
- Sample not collected
- * Duplicate samples taken; average value shown

Notes:

1) COC = Constituent of Concern (i.e., VC, TCE, and 1,2-DCE)

2) bgs = Below ground surface

3) Scale of cluster insets 1in = 3 ft.

GSI ENVIRONMENTAL

SOIL GAS SAMPLING AND TESTING RESULTS

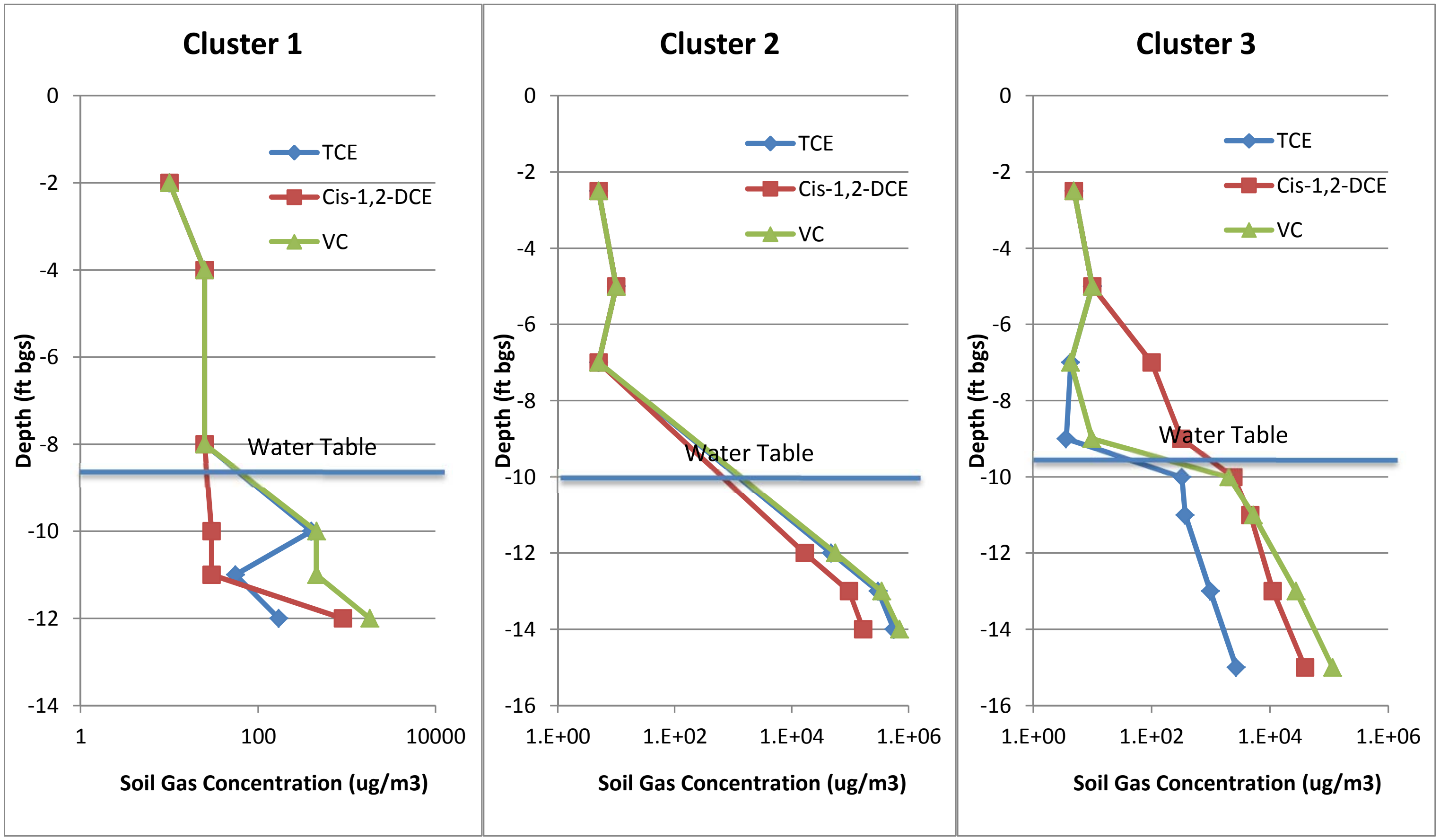
ESTCP Tier 2 Vapor Screening Study
Building 200, Tinker Air Force Base, Midwest City, Oklahoma

GSI Job No:	G-3213	Drawn By:	DLB
Issued:	18-Nov-11	Chk'd By:	RCL
Revised:	———	Appv'd By:	LMB
Scale:	As Shown		**FIGURE A.5.4**

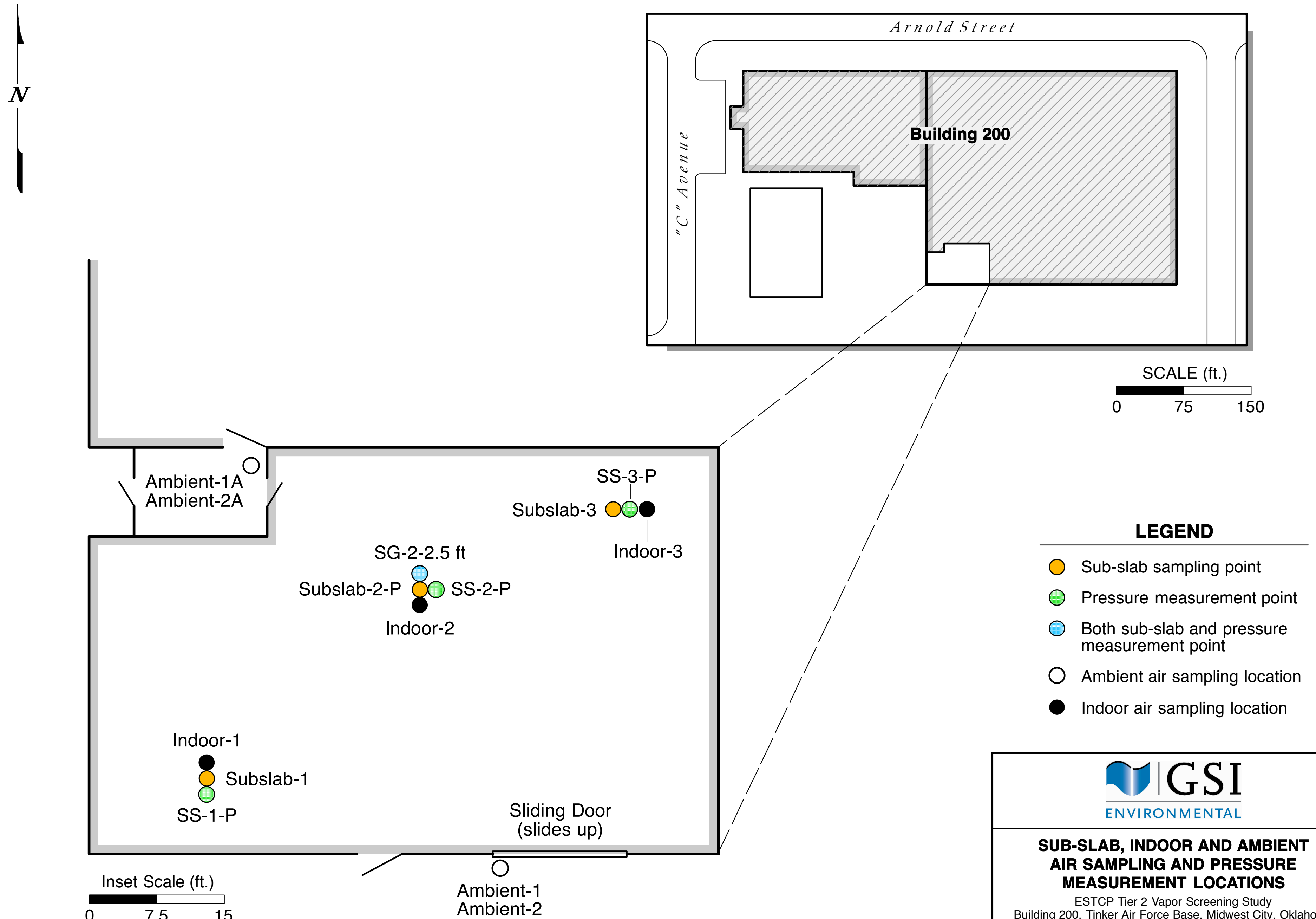
GSI Job No. G-3213
Issued: 18 November 2011

GSI ENVIRONMENTAL

FIGURE A.5.5
VERTICAL VOC PROFILE
ESTCP Tier 2 Vapor Screening Study
Tinker Air Force Base, Midwest City, OK



* = Concentrations in groundwater (i.e., below the water table) were converted into equivalent soil gas concentrations using Henry's Law assuming equilibrium partitioning.

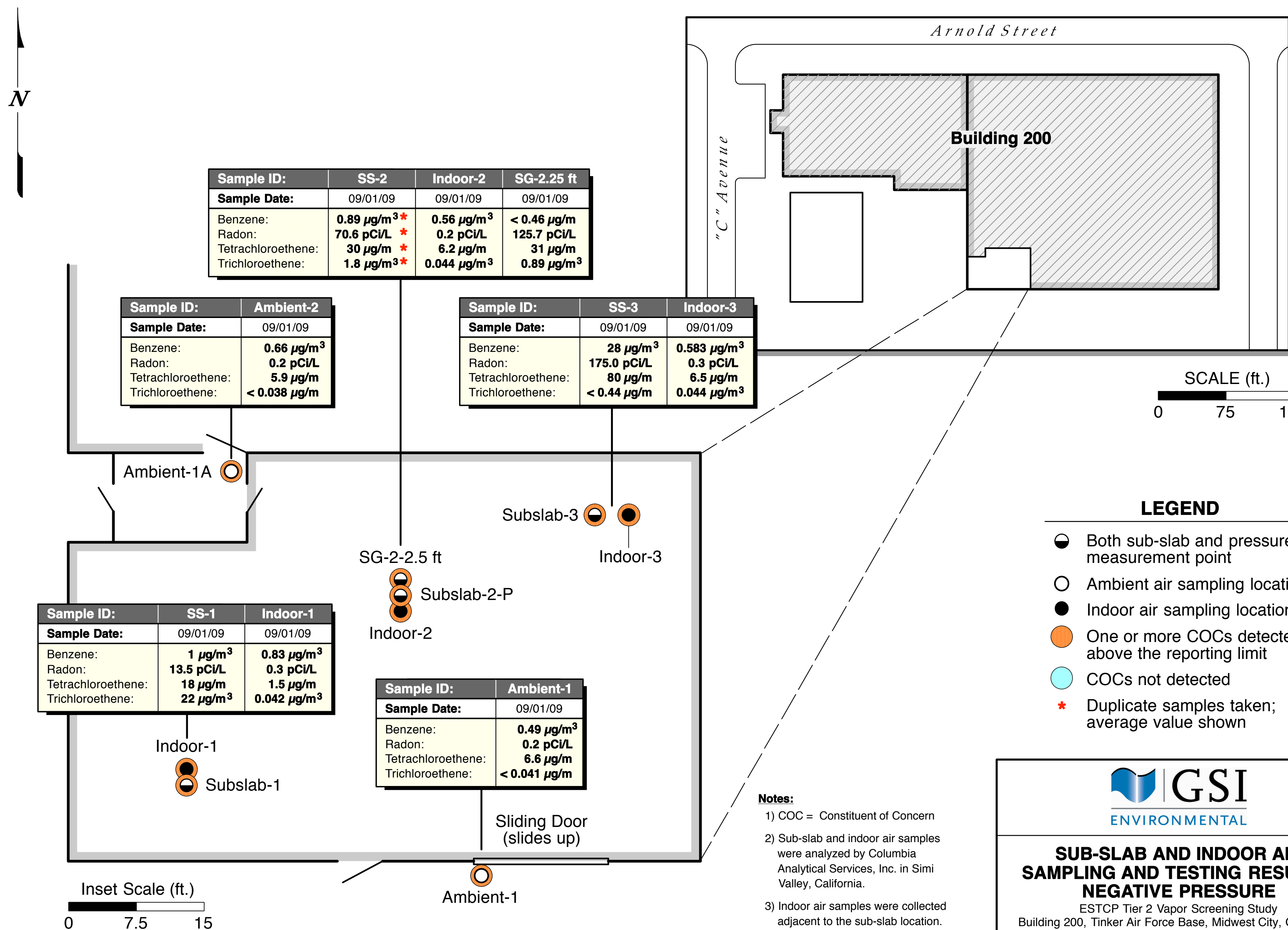


GSI ENVIRONMENTAL

SUB-SLAB, INDOOR AND AMBIENT AIR SAMPLING AND PRESSURE MEASUREMENT LOCATIONS

ESTCP Tier 2 Vapor Screening Study
Building 200, Tinker Air Force Base, Midwest City, Oklahoma

GSI Job No:	G-3213	Drawn By:	DLB
Issued:	18-Nov-11	Chk'd By:	RCL
Revised:	———	Appv'd By:	LMB
Scale:	As Shown		**FIGURE A.5.6**



Sample ID:	SS-2	Indoor-2	SG-2.25 ft
Sample Date:	09/01/09	09/01/09	09/01/09
Benzene:	**0.89 $\mu g/m^3$ ***	**0.56 $\mu g/m^3$**	**< 0.46 $\mu g/m$**
Radon:	**70.6 pCi/L ***	**0.2 pCi/L**	**125.7 pCi/L**
Tetrachloroethene:	**30 $\mu g/m$ ***	**6.2 $\mu g/m$**	**31 $\mu g/m$**
Trichloroethene:	**1.8 $\mu g/m^3$ ***	**0.044 $\mu g/m^3$**	**0.89 $\mu g/m^3$**

Sample ID:	Ambient-2
Sample Date:	09/01/09
Benzene:	**0.66 $\mu g/m^3$**
Radon:	**0.2 pCi/L**
Tetrachloroethene:	**5.9 $\mu g/m$**
Trichloroethene:	**< 0.038 $\mu g/m$**

Sample ID:	SS-3	Indoor-3
Sample Date:	09/01/09	09/01/09
Benzene:	**28 $\mu g/m^3$**	**0.583 $\mu g/m^3$**
Radon:	**175.0 pCi/L**	**0.3 pCi/L**
Tetrachloroethene:	**80 $\mu g/m$**	**6.5 $\mu g/m$**
Trichloroethene:	**< 0.44 $\mu g/m$**	**0.044 $\mu g/m^3$**

Sample ID:	SS-1	Indoor-1
Sample Date:	09/01/09	09/01/09
Benzene:	**1 $\mu g/m^3$**	**0.83 $\mu g/m^3$**
Radon:	**13.5 pCi/L**	**0.3 pCi/L**
Tetrachloroethene:	**18 $\mu g/m$**	**1.5 $\mu g/m$**
Trichloroethene:	**22 $\mu g/m^3$**	**0.042 $\mu g/m^3$**

Sample ID:	Ambient-1
Sample Date:	09/01/09
Benzene:	**0.49 $\mu g/m^3$**
Radon:	**0.2 pCi/L**
Tetrachloroethene:	**6.6 $\mu g/m$**
Trichloroethene:	**< 0.041 $\mu g/m$**

LEGEND

- Both sub-slab and pressure measurement point
- Ambient air sampling location
- Indoor air sampling location
- One or more COCs detected above the reporting limit
- COCs not detected
- * Duplicate samples taken; average value shown

Notes:

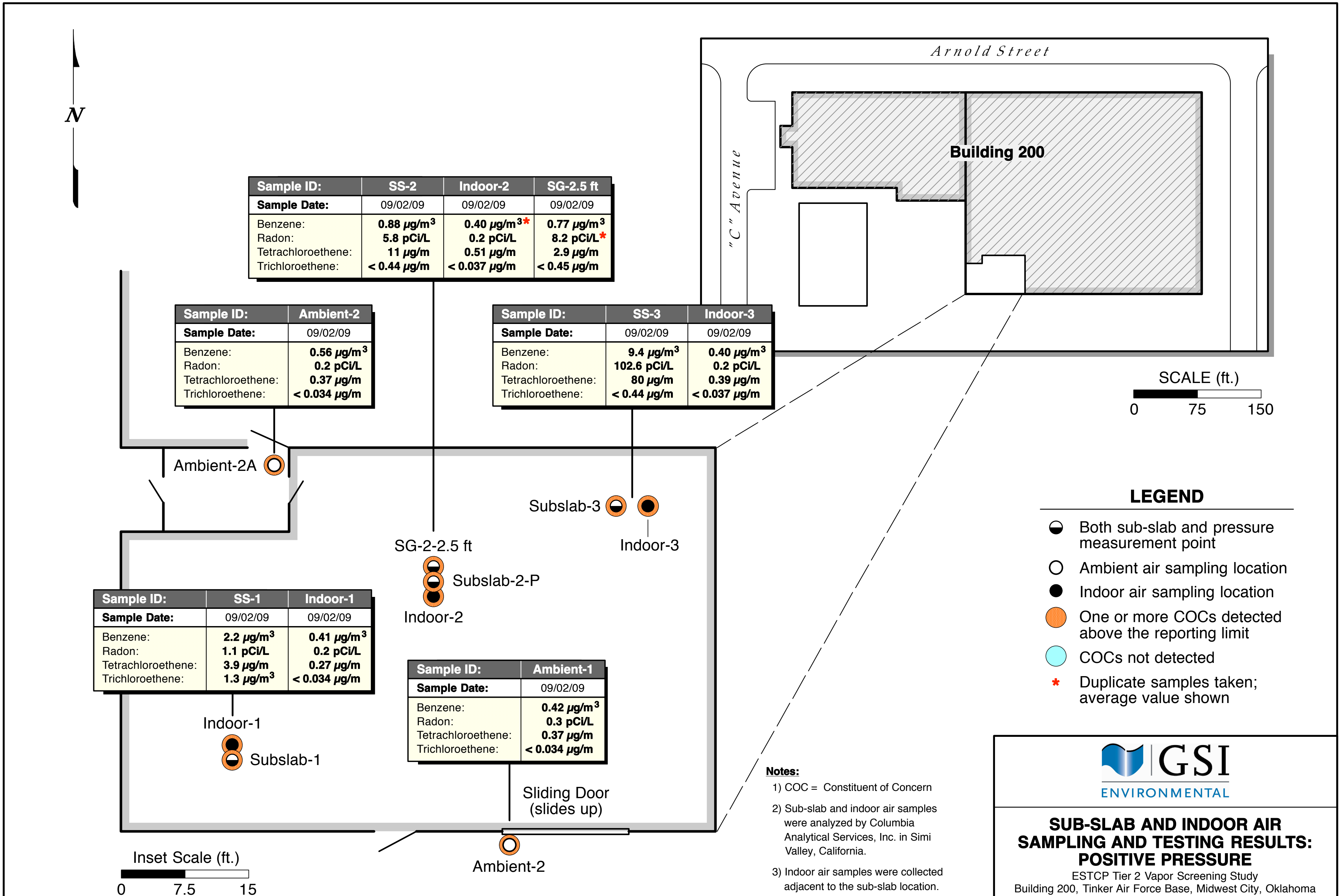
1) COC = Constituent of Concern
2) Sub-slab and indoor air samples were analyzed by Columbia Analytical Services, Inc. in Simi Valley, California.
3) Indoor air samples were collected adjacent to the sub-slab location.
4) Sub-slab samples, SS-1, SS-2, and SS-3 were collected 8 inches below the slab. SG-2 was collected 2.5 ft below the slab.

GSI ENVIRONMENTAL

SUB-SLAB AND INDOOR AIR SAMPLING AND TESTING RESULTS: NEGATIVE PRESSURE

ESTCP Tier 2 Vapor Screening Study
Building 200, Tinker Air Force Base, Midwest City, Oklahoma

GSI Job No:	G-3213	Drawn By:	DLB
Issued:	18-Nov-11	Chk'd By:	RCL
Revised:	———	Appv'd By:	LMB
Scale:	As Shown		**FIGURE A.5.7**



Sample ID:	SS-2	Indoor-2	SG-2.5 ft
Sample Date:	09/02/09	09/02/09	09/02/09
Benzene:	0.88 µg/m³	0.40 µg/m³ *	0.77 µg/m³
Radon:	5.8 pCi/L	0.2 pCi/L	8.2 pCi/L *
Tetrachloroethene:	11 µg/m	0.51 µg/m	2.9 µg/m
Trichloroethene:	< 0.44 µg/m	< 0.037 µg/m	< 0.45 µg/m

Sample ID:	Ambient-2
Sample Date:	09/02/09
Benzene:	0.56 µg/m³
Radon:	0.2 pCi/L
Tetrachloroethene:	0.37 µg/m
Trichloroethene:	< 0.034 µg/m

Sample ID:	SS-3	Indoor-3
Sample Date:	09/02/09	09/02/09
Benzene:	9.4 µg/m³	0.40 µg/m³
Radon:	102.6 pCi/L	0.2 pCi/L
Tetrachloroethene:	80 µg/m	0.39 µg/m
Trichloroethene:	< 0.44 µg/m	< 0.037 µg/m

Sample ID:	SS-1	Indoor-1
Sample Date:	09/02/09	09/02/09
Benzene:	2.2 µg/m³	0.41 µg/m³
Radon:	1.1 pCi/L	0.2 pCi/L
Tetrachloroethene:	3.9 µg/m	0.27 µg/m
Trichloroethene:	1.3 µg/m³	< 0.034 µg/m

Sample ID:	Ambient-1
Sample Date:	09/02/09
Benzene:	0.42 µg/m³
Radon:	0.3 pCi/L
Tetrachloroethene:	0.37 µg/m
Trichloroethene:	< 0.034 µg/m

LEGEND

- Both sub-slab and pressure measurement point
- Ambient air sampling location
- Indoor air sampling location
- One or more COCs detected above the reporting limit
- COCs not detected
- * Duplicate samples taken; average value shown

Notes:

1) COC = Constituent of Concern
2) Sub-slab and indoor air samples were analyzed by Columbia Analytical Services, Inc. in Simi Valley, California.
3) Indoor air samples were collected adjacent to the sub-slab location.
4) Sub-slab samples, SS-1, SS-2, and SS-3 were collected 8 inches below the slab. SG-2 was collected 2.5 ft below the slab.

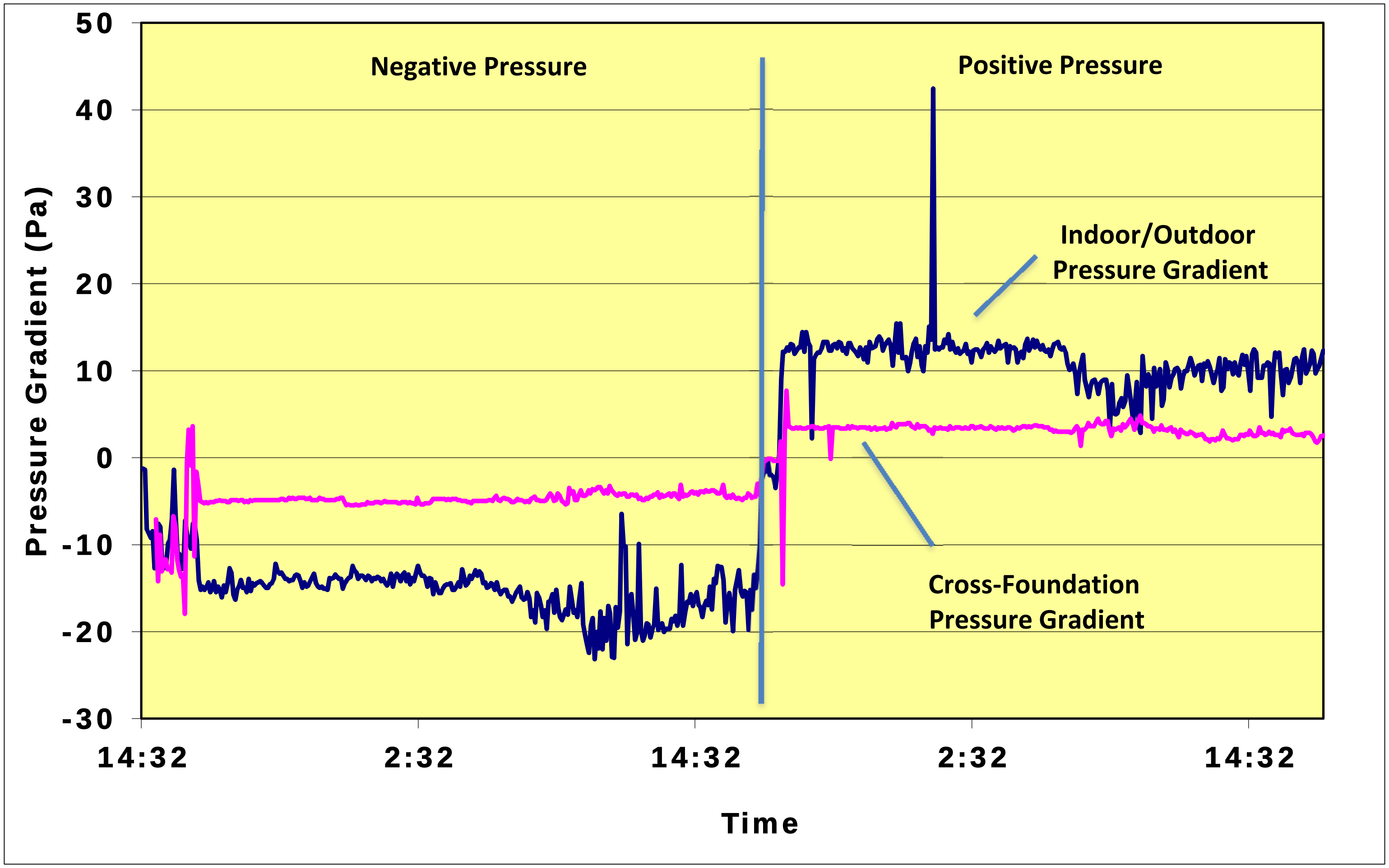
GSI ENVIRONMENTAL

SUB-SLAB AND INDOOR AIR SAMPLING AND TESTING RESULTS: POSITIVE PRESSURE

ESTCP Tier 2 Vapor Screening Study
Building 200, Tinker Air Force Base, Midwest City, Oklahoma

GSI Job No:	G-3213	Drawn By:	DLB
Issued:	18-Nov-11	Chk'd By:	RCL
Revised:	———	Appv'd By:	LMB
Scale:	As Shown		**FIGURE A.5.8**

FIGURE A.5.9
BUILDING PRESSURE GRADIENTS
ESTCP Tier 2 Vapor Screening Study
Building 200, Tinker Air Force Base, Midwest City, Oklahoma



Environmental Security Technology Certification Program
(ESTCP)

FINAL REPORT

Proposed Tier 2 Screening Criteria and Tier 3 Field Procedures for Evaluation of Vapor Intrusion
ESTCP Project ER-200707

Appendix A.6: Hill Air Force Base, Layton, Utah

TABLES

FIGURES

GSI ENVIRONMENTAL

TABLE A.6.1
RESULTS OF GEOTECHNICAL ANALYSES

ESTCP Tier 2 Vapor Screening Study

Operable Unit 5 Property
Hill Air Force Base, Utah

Sample ID	Sample Depth	Dry Bulk Density	Fraction Organic Carbon	Volumetric Water Content	Porosity Total	Porosity Air Filled	Intrinsic Permeability to Water (5 PSI Confining Stress)	Native Hydraulic Conductivity (5 PSI Confining Stress)
Units	**ft**	**pcf**	**%**	**%**	**--**	**--**	**cm^2**	**cm/sec**
C1-PZ-3	1-2	96.4	5.1	16.5	0.399	0.234	1.82E-10	1.78E-05
C1-PZ-3	3.5-4.5	102.5	1.4	33.1	0.378	0.047	3.20E-11	3.12E-06
C1-PZ-3	8-9	101.2	1.0	38.4	0.386	0.001	6.90E-12	6.74E-07
C1-PZ-3	12-13	103.9	0.7	36.1	0.373	0.012	2.20E-11	2.15E-06
C1-PZ-3	21.5-22.5	105.3	0.6	36.2	0.365	0.003	7.36E-10	7.19E-05
C2-PZ-2	1-2	103.1	1.2	12.4	0.377	0.252	2.08E-10	2.03E-05
C2-PZ-2	5-6	98.5	1.4	25.3	0.407	0.154	7.17E-10	7.00E-05
C2-PZ-2	11.5-12.5	109.9	0.8	32.8	0.335	0.006	1.67E-11	1.63E-06
C2-PZ-2	20-21	98.8	0.5	39.2	0.400	0.008	7.12E-09	6.95E-04
C3-PZ-2	0.5-1.5	92.8	6.1	14.5	0.422	0.277	5.23E-11	5.11E-06
C3-PZ-2	5.5-6.5	92.1	2.0	22.1	0.444	0.223	5.26E-10	5.13E-05
C3-PZ-2	7.5-8.5	102.6	1.1	36.1	0.382	0.021	6.71E-11	6.56E-06
C3-PZ-2	10-11	106.2	1.1	34.9	0.356	0.006	1.14E-11	1.12E-06
C3-PZ-2	12.5-13.5	103.4	0.4	35.7	0.370	0.012	5.17E-09	5.05E-04
C3-PZ-2	20-21	100.3	0.4	35.8	0.391	0.032	9.77E-12	9.54E-07

Notes:
1. Samples were analyzed by Fugro Consultants, Inc. in Houston, Texas (Report No. 04.11110042-2 Rev. 1)
2. Dry bulk density, volumetric moisture content, intrinsic permeability, and native hydraulic conductivity determined by ASTM Method D 5084; Fraction Organic Carbon determined by ASTM Method D 2974; and total and air-filled porosity determined by ASTM Method D 854.
3. All sample orientations were vertical.

TABLE A.6.2
SAMPLING POINT COMPLETION DETAILS: CLUSTERS

ESTCP Tier 2 Vapor Screening Study

Operable Unit 5 Property
Hill Air Force Base, Utah

Well ID	Installed Total Depth (ft, bgs)	Screen Interval Depth (ft, bgs)	Screen Slot Size (--)	Boring Hole Diameter (inches)	Well Diameter (inches)	Sand Backfill Filter Pack		Tubing Diameter (inches)
						U.S. Mesh Interval	Filter Pack Thickness (ft)	
Cluster 1								
Groundwater Sampling Points								
C1-PZ-1	22	21.5-22	No. 010	3.25	1	20/40	0.75	N/A
C1-PZ-2	14	13.5-14	No. 010	3.25	1	20/40	0.75	N/A
C1-PZ-3	12	11.5-12	No. 010	3.25	1	20/40	0.75	N/A
C1-PZ-4	8.5	8-8.5	No. 010	3.25	1	20/40	0.75	N/A
C1-PZ-5	6	5.5-6	No. 010	3.25	1	20/40	0.75	N/A
Soil Gas Sampling Points								
C1-SG-1	8.5	N/A	N/A	2.25	N/A	20/40	0.5	1/8
C1-SG-2	6	N/A	N/A	2.25	N/A	20/40	0.5	1/8
C1-SG-3	5	N/A	N/A	2.25	N/A	20/40	0.5	1/8
C1-SG-4	3.5	N/A	N/A	2.25	N/A	20/40	0.5	1/8
C1-SG-5	2.5	N/A	N/A	2.25	N/A	20/40	0.5	1/8
Cluster 2								
Groundwater Sampling Points								
C2-PZ-1	21	20.5-21	No. 010	3.25	1	20/40	0.75	N/A
C2-PZ-2	16	15.5-16	No. 010	3.25	1	20/40	0.75	N/A
C2-PZ-3	12	11.5-12	No. 010	3.25	1	20/40	0.75	N/A
C2-PZ-4	8.5	8-8.5	No. 010	3.25	1	20/40	0.75	N/A
C2-PZ-5	6.5	6-6.5	No. 010	3.25	1	20/40	0.75	N/A
Soil Gas Sampling Points								
C2-SG-1	8.5	N/A	N/A	2.25	N/A	20/40	0.5	1/8
C2-SG-2	6.5	N/A	N/A	2.25	N/A	20/40	0.5	1/8
C2-SG-3	5	N/A	N/A	2.25	N/A	20/40	0.5	1/8
C2-SG-4	4	N/A	N/A	2.25	N/A	20/40	0.5	1/8
C2-SG-5	3	N/A	N/A	2.25	N/A	20/40	0.5	1/8

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TABLE A.6.2 (CONTINUED)
SAMPLING POINT COMPLETION DETAILS: CLUSTERS
ESTCP Tier 2 Vapor Screening Study
Operable Unit 5 Property
Hill Air Force Base, Utah

Well ID	Installed Total Depth (ft, bgs)	Screen Interval Depth (ft, bgs)	Screen Slot Size (--)	Boring Hole Diameter (inches)	Well Diameter (inches)	Sand Backfill Filter Pack		Tubing Diameter (inches)
						U.S. Mesh Interval	Filter Pack Thickness (ft)	
Cluster 3								
Groundwater Sampling Points								
C3-PZ-1	21	20.5-21	No. 010	3.25	1	20/40	0.75	N/A
C3-PZ-2	16	15.5-16	No. 010	3.25	1	20/40	0.75	N/A
C3-PZ-3	12	11.5-12	No. 010	3.25	1	20/40	0.75	N/A
C3-PZ-4	8.5	8-8.5	No. 010	3.25	1	20/40	0.75	N/A
C3-PZ-5	6.5	6-6.5	No. 010	3.25	1	20/40	0.75	N/A
Soil Gas Sampling Points								
C3-SG-1	8.5	N/A	N/A	2.25	N/A	20/40	0.5	1/8
C3-SG-2	6.5	N/A	N/A	2.25	N/A	20/40	0.5	1/8
C3-SG-3	5.5	N/A	N/A	2.25	N/A	20/40	0.5	1/8
C3-SG-4	4.5	N/A	N/A	2.25	N/A	20/40	0.5	1/8
C3-SG-5	3	N/A	N/A	2.25	N/A	20/40	0.5	1/8

Notes:
1. Well locations are shown on Figure A.6.1.
2. All locations were completed with a bentonite seal.
3. bgs = Below ground surface.

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TABLE A.6.3
DEPTH TO WATER MEASUREMENTS

ESTCP Tier 2 Vapor Screening Study

Operable Unit 5 Property
Hill Air Force Base, Utah

Well ID	Installed Total Depth (ft, bgs)	Screen Interval Depth (ft, bgs)	8/24/2011 Depth to Water (ft, bgs)	8/26/2011 Depth to Water (ft, bgs)	Measured Total Depth (ft, bgs)
Cluster 1					
C1-PZ-1	22	21.5-22	11.01	11.07	22.1
C1-PZ-2	14	13.5-14	10.58	10.63	14.1
C1-PZ-3	12	11.5-12	10.51	10.55	12
C1-PZ-4	8.5	8-8.5	DRY	DRY	9
C1-PZ-5	6	5.5-6	DRY	DRY	6.3
Cluster 2					
C2-PZ-1	21	20.5-21	10.62	10.71	21.3
C2-PZ-2	16	15.5-16	10.68	10.70	16.3
C2-PZ-3	12	11.5-12	11.15	11.21	12.1
C2-PZ-4	8.5	8-8.5	DRY	DRY	8.5
C2-PZ-5	6.5	6-6.5	DRY	DRY	7
Cluster 3					
C3-PZ-1	21	20.5-21	11.31	11.35	21.1
C3-PZ-2	16	15.5-16	11.20	11.22	16.4
C3-PZ-3	12	11.5-12	11.20	11.23	12.2
C3-PZ-4	8.5	8-8.5	DRY	DRY	8
C3-PZ-5	6.5	6-6.5	DRY	DRY	6.9

Notes:
1. Well locations are shown on Figure A.6.1.
2. bgs = Below ground surface.

TABLE A.6.4
RESULTS OF GROUNDWATER ANALYSES: COMPOUNDS OF INTEREST

ESTCP Tier 2 Vapor Screening Study

Operable Unit 5 Property
Hill Air Force Base, Utah

		DUPLICATE					
SAMPLE LOCATION:	C1-PZ-1	C1-PZ-1	C1-PZ-2	C1-PZ-3	C2-PZ-1	C2-PZ-2	C2-PZ-3
SCREEN INTERVAL (ft, bgs):	21.5-22	21.5-22	13.5-14	11.5-12	20.5-21	15.5-16	11.5-12
SAMPLE DATE:	8/25/2011	8/25/2011	8/25/2011	8/25/2011	8/25/2011	8/25/2011	8/25/2011
COMPOUND	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Volatile Organic Compounds (VOCs) by USEPA Method 8260B							
Acetone	< 0.00099	< 0.00099	**0.098**	**0.0062**	< 0.00099	**0.0064**	< 0.00099
Benzene	< 0.00008	< 0.00008	**0.00013 J**	**0.00028 J**	< 0.00008	**0.00011 J**	**0.00014 J**
Butanone, 2- (MEK)	< 0.00076	< 0.00076	**0.024**	**0.028**	< 0.00076	**0.014**	**0.045**
Chloroform	**0.00081 J**	**0.00076 J**	**0.0004 J**	**0.00029 J**	**0.00097 J**	**0.0007 J**	**0.00052 J**
Dichloroethene, 1,1-	< 0.00019	< 0.00019	< 0.00019	< 0.00019	< 0.00019	< 0.00019	< 0.00019
Dichloroethene, cis-1,2-	< 0.00006	< 0.00006	< 0.00006	< 0.00006	< 0.00006	< 0.00006	< 0.00006
Dichloroethene, Total, 1,2-	< 0.0003	< 0.0003	< 0.0003	< 0.0003	< 0.0003	< 0.0003	< 0.0003
Ethylbenzene	< 0.00011	< 0.00011	< 0.00011	**0.00035 J**	< 0.00011	< 0.00011	< 0.00011
Toluene	< 0.00015	< 0.00015	**0.00044 J**	**0.003**	**0.00037 J**	**0.00038 J**	**0.00055 J**
Trichloroethane, 1,1,1-	< 0.00015	< 0.00015	< 0.00015	< 0.00015	< 0.00015	< 0.00015	< 0.00015
Trichloroethene	**0.005**	**0.0056**	**0.0012**	**0.00079 J**	**0.0078**	**0.0019**	**0.0009 J**
Xylene, m,p-	< 0.00017	< 0.00017	**0.00028 J**	**0.0019**	**0.00052 J**	**0.00017 J**	**0.00022 J**
Xylene, o-	< 0.00012	< 0.00012	< 0.00012	**0.00049 J**	**0.00014 J**	< 0.00012	< 0.00012
Xylenes, Total	< 0.00026	< 0.00026	**0.00028 J**	**0.0024**	**0.00066 J**	< 0.00026	< 0.00026

Continued on next page

TABLE A.6.4 (CONTINUED)

RESULTS OF GROUNDWATER ANALYSES: COMPOUNDS OF INTEREST

ESTCP Tier 2 Vapor Screening Study

Operable Unit 5 Property
Hill Air Force Base, Utah

SAMPLE LOCATION:	C3-PZ-1	C3-PZ-2	C3-PZ-3	Trip Blank
SCREEN INTERVAL (ft, bgs):	20.5-21	15.5-16	11.5-12	NA
SAMPLE DATE:	8/25/2011	8/25/2011	8/25/2011	8/25/2011
COMPOUND	mg/L	mg/L	mg/L	mg/L
Volatile Organic Compounds (VOCs) by USEPA Method 8260B				
Acetone	< 0.00099	< 0.00099	< 0.00099	< 0.00099
Benzene	< 0.00008	< 0.00008	< 0.00008	< 0.00008
Butanone, 2- (MEK)	< 0.00076	< 0.00076	< 0.00076	< 0.00076
Chloroform	**0.00018 J**	**0.0011**	**0.00065 J**	< 0.00013
Dichloroethene, 1,1-	**0.0018**	**0.0018**	< 0.00019	< 0.00019
Dichloroethene, cis-1,2-	**0.0019**	**0.0019**	< 0.00006	< 0.00006
Dichloroethene, Total, 1,2-	**0.0019**	**0.0019**	< 0.0003	< 0.0003
Ethylbenzene	< 0.00011	< 0.00011	< 0.00011	< 0.00011
Toluene	**0.00021 J**	< 0.00015	< 0.00015	< 0.00015
Trichloroethane, 1,1,1-	< 0.00015	**0.00028 J**	< 0.00015	< 0.00015
Trichloroethene	**0.023**	**0.024**	**0.0012**	< 0.00018
Xylene, m,p-	**0.00039 J**	< 0.00017	< 0.00017	< 0.00017
Xylene, o-	**0.00012 J**	< 0.00012	< 0.00012	< 0.00012
Xylenes, Total	**0.00051 J**	< 0.00026	< 0.00026	< 0.00026

Notes:
1. Sampling locations are shown on Figure A.6.1.
2. Samples were analyzed by TestAmerica Laboratories, Inc. in Houston, Texas by USEPA Method 8260B.
3. This table summarizes results for detected compounds. Detected analytes are presented in **bold** type.
4. < = Analyte not detected at or above the reporting limit.
J = Result is less than the reporting limit but greater than or equal to the method detection limit and the concentration is an approximate value.

TABLE A.6.5
RESULTS OF SOIL GAS ANALYSES: COMPOUNDS OF INTEREST

ESTCP Tier 2 Vapor Screening Study

Operable Unit 5 Property
Hill Air Force Base, Utah

			DUPLICATE					
SAMPLE LOCATION:	C1-SG-1	C1-SG-2	C1-SG-2	C1-SG-3	C1-SG-4	C1-SG-5	C2-SG-1	C2-SG-2
SCREEN INTERVAL (ft, bgs):	8-8.5	5.5-6	5.5-6	4.5-5	3-3.5	2-2.5	8-8.5	6-6.5
SAMPLE DATE:	8/25/2011	8/25/2011	8/25/2011	8/25/2011	8/25/2011	8/25/2011	8/25/2011	8/25/2011
SAMPLE COLLECTION METHOD:	1-L Summa	1-L Summa	1-L Summa	1-L Summa	1-L Summa	1-L Summa	1-L Summa	1-L Summa
COMPOUND	μg/m³	μg/m³	μg/m³	μg/m³	μg/m³	μg/m³	μg/m³	μg/m³
Volatile Organic Compounds (VOCs) by USEPA Method TO-15								
Acetone	**64**	**68**	**65**	**35**	**77**	**130**	**51**	**36**
Benzene	**30**	**5.9**	**3.6**	**4.6**	**3.1**	<2.1	**13**	**4.3**
Butanone, 2-	<24	**22**	**23**	<22	**23**	**23**	<20	<21
Chloroform	**14**	**4.2**	**4.4**	**14**	**17**	**10**	**90**	**34**
Dichloroethene, 1,1-	<2.4	<2.1	<2	<2.2	<2.2	<2.1	<2	<2.1
Dichloroethene, cis-1,2-	<2.4	<2.1	<2	<2.2	<2.2	<2.1	<2	<2.1
Dichloroethene, trans-1,2-	<2.4	<2.1	<2	<2.2	<2.2	<2.1	<2	<2.1
Ethylbenzene	**94**	**6.7**	**5.1**	**12**	<2.2	<2.1	**2.1**	**12**
Toluene	**250**	**15**	**10**	**18**	**3.4**	**4.1**	**14**	**37**
Trichloroethane, 1,1,1-	<2.4	<2.1	<2	<2.2	<2.2	<2.1	**4.2**	**6.6**
Trichloroethene	**26**	**7.3**	**7.6**	**3**	<2.2	<2.1	**79**	**170**
Xylene, m,p-	**490**	**39**	**31**	**81**	**16**	**9.7**	**15**	**70**
Xylene, o-	**110**	**14**	**11**	**23**	**9.1**	**6.8**	**12**	**19**
Helium by Method 3C Modified								
Helium	<7,700	<7,000	<6,700	<7,100	<7,000	<7,000	<6,600	<6,700

Continued on next page

TABLE A.6.5 (CONTINUED)

RESULTS OF SOIL GAS ANALYSES: COMPOUNDS OF INTEREST

ESTCP Tier 2 Vapor Screening Study

Operable Unit 5 Property
Hill Air Force Base, Utah

SAMPLE LOCATION:	C2-SG-3	C2-SG-4	C2-SG-5	C3-SG-1	C3-SG-2	C3-SG-3	C3-SG-4	C3-SG-5
SCREEN INTERVAL (ft, bgs):	4.5-5	3.5-4	2.5-3	8-8.5	6-6.5	5-5.5	4-4.5	2.5-3
SAMPLE DATE:	8/25/2011	8/25/2011	8/25/2011	8/26/2011	8/26/2011	8/26/2011	8/26/2011	8/26/2011
SAMPLE COLLECTION METHOD:	1-L Summa	1-L Summa	1-L Summa	1-L Summa	1-L Summa	1-L Summa	1-L Summa	1-L Summa
COMPOUND	μg/m^3	μg/m^3	μg/m^3	μg/m^3	μg/m^3	μg/m^3	μg/m^3	μg/m^3
Volatile Organic Compounds (VOCs) by USEPA Method TO-15								
Acetone	**34**	**26**	**43**	**35**	**46**	**55**	**33**	**75**
Benzene	**8.6**	**13**	**11**	**12**	**7.4**	**5.3**	**6.5**	<2
Butanone, 2-	<20	<21	<21	<20	<19	<20	<20	<20
Chloroform	**54**	**63**	**100**	**14**	**9.3**	**8.4**	**12**	**18**
Dichloroethene, 1,1-	<2	<2.1	<2.1	<2	<1.9	<2	<2	<2
Dichloroethene, cis-1,2-	<2	<2.1	<2.1	<2	<1.9	<2	<2	<2
Dichloroethene, trans-1,2-	<2	<2.1	<2.1	<2	<1.9	<2	<2	<2
Ethylbenzene	**23**	**28**	**53**	**12**	**3.5**	**3.6**	**2.9**	<2
Toluene	**63**	**77**	**84**	**34**	**9**	**4.7**	**4.7**	<2
Trichloroethane, 1,1,1-	**5.9**	**5.3**	<2.1	**4.6**	**2.3**	<2	<2	<2
Trichloroethene	**150**	**110**	**10**	**120**	**36**	**29**	**14**	**2.3**
Xylene, m,p-	**140**	**160**	**350**	**59**	**15**	**18**	**15**	**4.3**
Xylene, o-	**38**	**41**	**95**	**17**	**5.3**	**7**	**5.6**	**3.8**
Helium by Method 3C Modified								
Helium	<6,600	<6,700	**220,000**	<6,400	<6,300	<6,400	<6,400	<6,400

Notes:
1. Sampling locations are shown on Figure A.6.1.
2. Compounds of interest shown in this table include compounds detected in groundwater plus helium (leak tracer). Average helium release rate: 1 Liter / minute.
3. Samples were analyzed by Columbia Analytical Services in Simi Valley, California.
4. Detected analytes are presented in **bold** type.
5. < = Analyte not detected at or above the reporting limit.

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TABLE A.6.6
RESULTS OF SOIL PERMEABILITY TESTING

ESTCP Tier 2 Vapor Screening Study
OU5 Property, Hill Air Force Base, Clifton, Utah

Cluster Location	Sample Point	Air Flow Rate (Q) (L/min)	Air Flow Rate (Q) (cc/min)	Vacuum (P) (in. Hg)	Vacuum (P) (in. H2O)	Slope of Q vs. P	Permeability (cm2)
Cluster 1	PZ-5	4.0	4000	0.2	2.4	843	2.32E-08
		6.0	6000	0.3	4.2		
		8.0	8000	0.5	6.8		
		10.0	10000	0.6	8.8		
		12.0	12000	0.9	12.0		
		14.0	14000	1.0	13.5		
		16.0	16000	1.2	16.5		
		14.0	14000	1.0	14.25		
		12.0	12000	0.8	11.25		
		10.0	10000	0.6	8.5		
		8.0	8000	0.5	6.6		
		6.0	6000	0.3	4.2		
		4.0	4000	0.2	2.45		
	PZ-4	0.2	200	0.1	1.2	46	1.27E-09
		0.6	600	0.2	2.25		
		1.0	1000	0.3	3.6		
		2.0	2000	0.7	9.8		
		4.0	4000	1.7	22.5		
		6.0	6000	8.0	108.8		
		10.0	10000	14.5	197.2		
		6.0	6000	8.0	108.8		
		4.0	4000	1.7	23.0		
		2.0	2000	0.7	9.8		
		1.0	1000	0.3	4.2		
		0.6	600	0.2	2.8		
		0.2	200	0.1	1.4		

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TABLE A.6.6 (CONTINUED)
RESULTS OF SOIL PERMEABILITY TESTING

ESTCP Tier 2 Vapor Screening Study
OU5 Property, Hill Air Force Base, Clifton, Utah

Cluster Location	Sample Point	Air Flow Rate (Q)		Vacuum (P)		Slope of Q vs. P	Permeability (cm2)
		(L/min)	(cc/min)	(in. Hg)	(in. H2O)		
Cluster 2	PZ-5	4.0	4000	0.1	0.7	1537.11	4.23E-08
		6.0	6000	0.1	1.0		
		8.0	8000	0.1	1.8		
		10.0	10000	0.2	2.5		
		14.0	14000	0.4	5.25		
		18.0	18000	0.7	9.8		
		14.0	14000	0.4	5.6		
		10.0	10000	0.2	2.8		
		8.0	8000	0.1	1.8		
		6.0	6000	0.1	1.2		
		4.0	4000	0.1	0.7		
	PZ-4	4.0	4000	0.0	0.6	1848	5.08E-08
		6.0	6000	0.1	0.8		
		8.0	8000	0.1	1.2		
		10.0	10000	0.1	1.6		
		14.0	14000	0.2	3.2		
		18.0	18000	0.5	7.2		
		20.0	20000	0.6	8.6		
		18.0	18000	0.5	7.2		
		14.0	14000	0.3	4.25		
		10.0	10000	0.2	2.2		
		8.0	8000	0.1	1.2		
		6.0	6000	0.1	0.8		
		4.0	4000	0.0	0.5		

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TABLE A.6.6 (CONTINUED)
RESULTS OF SOIL PERMEABILITY TESTING

ESTCP Tier 2 Vapor Screening Study
OU5 Property, Hill Air Force Base, Clifton, Utah

Cluster Location	Sample Point	Air Flow Rate (Q) (L/min)	Air Flow Rate (Q) (cc/min)	Vacuum (P) (in. Hg)	Vacuum (P) (in. H2O)	Slope of Q vs. P	Permeability (cm2)
Cluster 3	PZ-5	3.0	3000	0.2	2.4	606.8	1.67E-08
		5.0	5000	0.4	4.8		
		8.0	8000	0.7	9.4		
		10.0	10000	0.9	12.6		
		12.0	12000	1.1	15.3		
		16.0	16000	1.7	23.0		
		18.0	18000	2.0	26.8		
		16.0	16000	1.8	24.0		
		12.0	12000	1.2	16.0		
		10.0	10000	0.8	11.3		
		8.0	8000	0.7	9.8		
		5.0	5000	0.4	5.0		
		3.0	3000	0.2	2.4		
	PZ-4	4.0	4000	0.2	2.6	713	1.96E-08
		6.0	6000	0.3	4.6		
		8.0	8000	0.5	7.2		
		10.0	10000	0.7	9.2		
		12.0	12000	0.9	12.8		
		16.0	16000	1.3	18.3		
		18.0	18000	1.6	22.3		
		16.0	16000	1.4	19.0		
		12.0	12000	0.9	12.6		
		10.0	10000	0.7	9.0		
		8.0	8000	0.5	7.3		
		6.0	6000	0.3	4.6		
		4.0	4000	0.2	2.6		

Parameter	Symbol	Value	Units	Basis
Viscosity of air	viscosity	1.73E-04	g/cm-s (poise)	Literature (40 deg. F)
Length: Mont. Well	L	15.2	cm	Screen length for monitoring well points (6 inches)
Diameter: Mont. Well	D	3.2	cm	Inside diameter for monitoring well points
Units Conversion		1.07E-06		From calculation methods sheet
L/D Term: Well Pt		0.1486		Calculated

TABLE A.6.7
SAMPLING POINT COMPLETION DETAILS: SUB-SLAB AND PRESSURE MEASUREMENT
ESTCP Tier 2 Vapor Screening Study
ASU Research House, Layton, Utah

Location ID	Installed Total Depth (ft, bgs)	Boring Hole Diameter (inches)	Sand Backfill Filter Pack		Tubing Diameter (inches)
			U.S. Mesh Interval	Filter Pack Thickness (in)	
Sub-Slab Sampling Points					
SS-1	0.67	1	20/40	1	1/4
SS-2	0.67	1	20/40	1	1/4
SS-3	0.67	1	20/40	1	1/4
Pressure Measurement Points					
SS-1-P [4]	0.67	1	20/40	1	1/4
SS-2-P	0.67	1	20/40	1	1/4
SS-3-P [4]	0.67	1	20/40	1	1/4

Notes:
1. Locations are shown on Figure A.6.6.
2. Except for SS-2, locations were completed to the surface with a bentonite seal topped with modeling clay.
SS-2 was collected from a permanent probe point installed by ASU researchers.
3. bgs = Below ground surface.
4. Pressure measurement from the same point as sub-slab sample.

TABLE A.6.8
RESULTS OF SUB-SLAB ANALYSES: COMPOUNDS OF INTEREST
ESTCP Tier 2 Vapor Screening Study
ASU Research House, Layton, UT

LOCATION ID:	Subslab-1	Subslab-1	Subslab-1	Subslab-1	Subslab-1	Subslab-1
PRESSURE CONDITION:	Baseline	Negative	Positive	Baseline	Negative	Positive
SAMPLE DATE:	10/2/2010	10/3/2010	10/4/2010	10/5/2010	10/6/2010	10/7/2010
VOCS ANALYTICAL METHOD:	TO-15 SIM	TO-15 SIM	TO-15 SIM	TO-15	TO-15	TO-15
COMPOUND	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$
Volatile Organic Compounds (VOCs) by Method TO-15 SIM or TO-15						
Benzene	**0.29**	**0.21**	**0.19**	**0.42**	**0.84**	<0.39
Dichloroethene, 1,1-	**16**	**16**	**18**	**13**	**14**	**20**
Toluene	**1.4**	**0.52**	**0.76**	**3.8**	**12**	<1.9
Trichloroethene	**20**	**9.8**	**12**	**14**	**8.6**	**13**
Radon by EPA Method GS						
Radon, pCi/L	-	-	-	**451.46**	**412.77**	**470.77**
Radon by RAD7 on-site instrument						
Radon, pCi/L	**670.58** [5]	**622.92**	**600.12**	**437.08**	**433.44**	**411.1**
Sulfur Hexafluoride (SF6) by NIOSH 6602 Modified						
Sulfur Hexafluoride	**600**	**130**	**380**	**290**	**120**	**370**

Notes:
1. VOC and SF6 samples were analyzed by Columbia Analytical Services, Inc. in Simi Valley, California. Radon laboratory analysis conducted by USC.
2. Detected analytes are presented in **bold** type.
3. < = not detected at detection limit shown; "-" = not analyzed.
4. D = reported result is from a dilution.
5. The RAD7 instrument was programmed to report 5 measurements, with a cycle time of 5 minutes. The final concentration was calculated as the average of the last three measurements (i.e., Cycles 3, 4 and 5). Subslab-1 Baseline (10/2/2010) is the average of the normal and duplicate result.
6. Compounds shown are those included in Tier 3 pressure control evaluation.

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TABLE A.6.8 (CONTINUED)

RESULTS OF SUB-SLAB ANALYSES: COMPOUNDS OF INTEREST
ESTCP Tier 2 Vapor Screening Study
ASU Research House, Layton, UT

		DUPLICATE					*DUPLICATE*	
LOCATION ID:	Subslab-2	Subslab-2	Subslab-2	Subslab-2	Subslab-2	Subslab-2	Subslab-2	Subslab-2
PRESSURE CONDITION:	Baseline	Baseline	Negative	Positive	Baseline	Negative	Negative	Positive
SAMPLE DATE:	10/2/2010	10/2/2010	10/3/2010	10/4/2010	10/5/2010	10/6/2010	10/6/2010	10/7/2010
VOCS ANALYTICAL METHOD:	TO-15 SIM	TO-15 SIM	TO-15 SIM	TO-15 SIM	TO-15	TO-15	TO-15	TO-15
COMPOUND	μg/m^3	μg/m^3	μg/m^3	μg/m^3	μg/m^3	μg/m^3	μg/m^3	μg/m^3
Volatile Organic Compounds (VOCs) by Method TO-15 SIM or TO-15								
Benzene	**0.11**	**0.11**	<1.3	**0.1**	<0.38	**0.64**	**0.81**	<0.39
Dichloroethene, 1,1-	**0.098**	**0.11**	**240**	**0.35**	<0.38	**310**	**350**	**0.43**
Toluene	**0.36**	**0.35**	**3.9**	**0.38**	<1.9	<2	**2.5**	<2
Trichloroethene	**12**	**12**	**320**	**4.6**	**7**	**390**	**420 D**	**8.6**
Radon by EPA Method GS								
Radon	-	-	-	-	**85.04**	**105.54**	**99.26**	**31.73**
Radon by RAD7 on-site instrument								
Radon, pCi/L	**68.87**	-	**74.31**	**28.83**	**80.4**	**105.71**	**112.43**	**45.56**
Sulfur Hexafluoride (SF6) by NIOSH 6602 Modified								
Sulfur Hexafluoride	**2400**	**2600**	**24**	**1500**	**260**	**14**	**18**	**1000**

Notes:

1. VOC and SF6 samples were analyzed by Columbia Analytical Services, Inc. in Simi Valley, California. Radon laboratory analysis conducted by USC.
2. Detected analytes are presented in **bold** type.
3. < = not detected at detection limit shown; "-" = not analyzed.
4. D = reported result is from a dilution.
5. The RAD7 instrument was programmed to report 5 measurements, with a cycle time of 5 minutes. The final concentration was calculated as the average of the last three measurements (i.e., Cycles 3, 4 and 5)
6. Compounds shown are those included in Tier 3 pressure control evaluation.

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TABLE A.6.8 (CONTINUED)

RESULTS OF SUB-SLAB ANALYSES: COMPOUNDS OF INTEREST

ESTCP Tier 2 Vapor Screening Study

ASU Research House, Layton, UT

LOCATION ID:	Subslab-3	Subslab-3	Subslab-3	Subslab-3	Subslab-3	Subslab-3
PRESSURE CONDITION:	Baseline	Negative	Positive	Baseline	Negative	Positive
SAMPLE DATE:	10/2/2010	10/3/2010	10/4/2010	10/5/2010	10/6/2010	10/7/2010
VOCS ANALYTICAL METHOD:	TO-15 SIM	TO-15 SIM	TO-15 SIM	TO-15	TO-15	TO-15
COMPOUND	µg/m^3	µg/m^3	µg/m^3	µg/m^3	µg/m^3	µg/m^3
Volatile Organic Compounds (VOCs) by Method TO-15 SIM or TO-15						
Benzene	**0.35**	<1.3	**0.34**	**0.37**	**0.65**	**0.58**
Dichloroethene, 1,1-	**0.088**	**250**	**1.2**	**0.95**	**350**	**2.2**
Toluene	**7.7**	<1.7	**1.3**	**2.4**	<2	**3.7**
Trichloroethene	**2.3**	**330**	**4.1**	**9.9**	**390 D**	**7.2**
Radon by EPA Method GS						
Radon, pCi/L	-	-	-	**15.36**	**103.96**	**2.41**
Radon by RAD7 on-site instrument						
Radon, pCi/L	**16.25**	**87.12**	**4.47**	**16.25**	**113.39**	**6.04**
Sulfur Hexafluoride (SF6) by NIOSH 6602 Modified						
Sulfur Hexafluoride	**3900**	**15**	**1800**	**1700**	**24**	**1600**

Notes:

1. VOC and SF6 samples were analyzed by Columbia Analytical Services, Inc. in Simi Valley, California. Radon laboratory analysis conducted by USC.
2. Detected analytes are presented in **bold** type.
3. < = not detected at detection limit shown; "-" = not analyzed.
4. D = reported result is from a dilution.
5. The RAD7 instrument was programmed to report 5 measurements, with a cycle time of 5 minutes. The final concentration was calculated as the average of the last three measurements (i.e., Cycles 3, 4 and 5)
6. Compounds shown are those included in Tier 3 pressure control evaluation.

TABLE A.6.9
RESULTS OF INDOOR AND AMBIENT AIR ANALYSES: COMPOUNDS OF INTEREST
ESTCP Tier 2 Vapor Screening Study
ASU Research House, Layton, UT

LOCATION ID:	Indoor-1	Indoor-1	Indoor-1	Indoor-1	Indoor-1	Indoor-1
PRESSURE CONDITION:	Baseline	Negative	Positive	Baseline	Negative	Positive
SAMPLE DATE:	10/2/2010	10/3/2010	10/4/2010	10/5/2010	10/6/2010	10/7/2010
COMPOUND	µg/m^3	µg/m^3	µg/m^3	µg/m^3	µg/m^3	µg/m^3
Volatile Organic Compounds (VOCs) by Method TO-15 SIM						
Benzene	**0.56**	**0.45**	**0.59**	**0.47**	**0.44**	**0.56**
Dichloroethene, 1,1-	**0.12**	**2**	<0.041	**0.12**	**2.3**	<0.041
Toluene	**2.6**	**1.5**	**2.9**	**6.8**	**2.1**	**1.8**
Trichloroethene	**6.3**	**4**	**0.59**	**18**	**4**	**0.11**
Radon by EPA Method GS						
Radon, pCi/L	**0.36**	**0.83**	0	**0.27**	**1.10**	**0.02**
Sulfur Hexafluoride (SF6) by NIOSH 6602 Modified						
Sulfur Hexafluoride	**7700**	**420**	**85**	**4000**	**360**	**82**

Notes:
1. VOC and SF6 samples were analyzed by Columbia Analytical Services, Inc. in Simi Valley, California. Radon laboratory analysis conducted by USC.
2. Detected analytes are presented in **bold** type.
3. < = not detected at detection limit shown; "-" = not analyzed.
4. Compounds shown are those included in Tier 3 pressure control evaluation.

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TABLE A.6.9 (CONTINUED)
RESULTS OF INDOOR AND AMBIENT AIR ANALYSES: COMPOUNDS OF INTEREST
ESTCP Tier 2 Vapor Screening Study
ASU Research House, Layton, UT

			DUPLICATE			*DUPLICATE*		
LOCATION ID:	Indoor-2	Indoor-2	Indoor-2	Indoor-2	Indoor-2	Indoor-2	Indoor-2	Indoor-2
PRESSURE CONDITION:	Baseline	Negative	Negative	Positive	Baseline	Baseline	Negative	Positive
SAMPLE DATE:	10/2/2010	10/3/2010	10/3/2010	10/4/2010	10/5/2010	10/5/2010	10/6/2010	10/7/2010
COMPOUND	μg/m^3	μg/m^3	μg/m^3	μg/m^3	μg/m^3	μg/m^3	μg/m^3	μg/m^3
Volatile Organic Compounds (VOCs) by Method TO-15 SIM								
Benzene	**0.42**	**0.44**	**0.45**	**0.6**	**0.46**	**0.47**	**0.47**	**0.57**
Dichloroethene, 1,1-	**0.12**	**13**	**11**	<0.047	**0.13**	**0.13**	**11**	<0.047
Toluene	**1.8**	**1.3**	**1.1**	**2.4**	**2.2**	**4.3**	**4.4**	**2.3**
Trichloroethene	**7.1**	**19**	**17**	**0.2**	**22**	**23**	**16**	**0.15**
Radon by EPA Method GS								
Radon, pCi/L	**0.36**	**3.02**	**4.52**	**0.10**	**0.33**	**0.34**	**4.12**	**0.15**
Sulfur Hexafluoride (SF6) by NIOSH 6602 Modified								
Sulfur Hexafluoride	**8000**	**520**	**630**	**1800**	**5100**	**4900**	**380**	**820**

Notes:
1. VOC and SF6 samples were analyzed by Columbia Analytical Services, Inc. in Simi Valley, California. Radon laboratory analysis conducted by USC.
2. Detected analytes are presented in **bold** type.
3. < = not detected at detection limit shown; "-" = not analyzed.
4. Compounds shown are those included in Tier 3 pressure control evaluation.

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TABLE A.6.9 (CONTINUED)
RESULTS OF INDOOR AND AMBIENT AIR ANALYSES: COMPOUNDS OF INTEREST
ESTCP Tier 2 Vapor Screening Study
ASU Research House, Layton, UT

LOCATION ID:	Indoor-3	Indoor-3	Indoor-3	Indoor-3	Indoor-3	Indoor-3
PRESSURE CONDITION:	Baseline	Negative	Positive	Baseline	Negative	Positive
SAMPLE DATE:	10/2/2010	10/3/2010	10/4/2010	10/5/2010	10/6/2010	10/7/2010
COMPOUND	µg/m^3	µg/m^3	µg/m^3	µg/m^3	µg/m^3	µg/m^3
Volatile Organic Compounds (VOCs) by Method TO-15 SIM						
Benzene	**0.45**	**0.46**	**0.47**	**0.44**	**0.46**	**0.59**
Dichloroethene, 1,1-	**0.16**	**4.3**	**0.044**	**0.12**	**5.4**	<0.039
Toluene	**2.2**	**1.5**	**2.1**	**2.2**	**2.7**	**2.7**
Trichloroethene	**7**	**7.4**	**0.21**	**16**	**8.4**	**0.18**
Radon by EPA Method GS						
Radon, pCi/L	**0.46**	**2.71**	0	**0.53**	**0.38**	**0.10**
Sulfur Hexafluoride (SF6) by NIOSH 6602 Modified						
Sulfur Hexafluoride	**11000**	**2400**	**2900**	**6500**	**1600**	**1700**

Notes:
1. VOC and SF6 samples were analyzed by Columbia Analytical Services, Inc. in Simi Valley, California. Radon laboratory analysis conducted by USC.
2. Detected analytes are presented in **bold** type.
3. < = not detected at detection limit shown; "-" = not analyzed.
4. Compounds shown are those included in Tier 3 pressure control evaluation.

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TABLE A.6.9 (CONTINUED)

RESULTS OF INDOOR AND AMBIENT AIR ANALYSES: COMPOUNDS OF INTEREST
ESTCP Tier 2 Vapor Screening Study
ASU Research House, Layton, UT

							DUPLICATE
LOCATION ID:	Ambient-1	Ambient-1	Ambient-1	Ambient-1	Ambient-1	Ambient-1	Ambient-1
PRESSURE CONDITION:	Baseline	Negative	Positive	Baseline	Negative	Positive	Positive
SAMPLE DATE:	10/2/2010	10/3/2010	10/4/2010	10/5/2010	10/6/2010	10/7/2010	10/7/2010
COMPOUND	µg/m^3	µg/m^3	µg/m^3	µg/m^3	µg/m^3	µg/m^3	µg/m^3
Volatile Organic Compounds (VOCs) by Method TO-15 SIM							
Benzene	**0.5**	**0.39**	**0.54**	**0.39**	**0.42**	**0.68**	**0.45**
Dichloroethene, 1,1-	<0.038	<0.041	<0.05	<0.037	<0.039	<0.036	<0.042
Toluene	**1.5**	**0.87**	**2.2**	**3.9**	**1.9**	**2.1**	**1.5**
Trichloroethene	**0.21**	**0.12**	**0.13**	**0.17**	**0.15**	**0.045**	**0.084**
Radon by EPA Method GS							
Radon, pCi/L	**0.48**	**0.18**	**0.09**	**0.10**	**0.03**	**0.07**	-
Sulfur Hexafluoride (SF6) by NIOSH 6602 Modified							
Sulfur Hexafluoride	**12**	<9.8	<12	<8.8	**12**	**12**	<10

Notes:

1. VOC and SF6 samples were analyzed by Columbia Analytical Services, Inc. in Simi Valley, California. Radon laboratory analysis conducted by USC.
2. Detected analytes are presented in **bold** type.
3. < = not detected at detection limit shown; "-" = not analyzed.
4. Compounds shown are those included in Tier 3 pressure control evaluation.

TABLE A.6.10
PRESSURE GRADIENT MEASUREMENTS FROM ADDITIONAL LOCATIONS
ESTCP Tier 2 Vapor Screening Study
ASU Research House, Layton, Utah

Condition	Pressure Gradient (Pa)				
	Time	**Through Front Door**	**Across Door to Garage**	**SS-1 (in garage)**	**SS-3**
Round 1					
Depressurization with fan on medium (Speed 2)	10/3/10 6:50	-3.984 to -6.225	-0.996	0.000 to +0.498 (door from garage to house closed) -0.747 (door from garage to house open)	-0.498
Depressurization with fan on medium (Speed 2)	10/3/10 15:15	-5.478 to -5.976	-4.731	0.747 (door closed) -0.498 (door open)	-0.747
Pressurization with fan on medium (Speed 2)	10/4/10 15:36	NR	0.000 to 2.49	-0.498 to 0.000 (door closed) +0.498 to 0.000 (door open)	0.000 to 2.49
Round 2					
Baseline (no fan)	10/5/10 17:00	NR	-0.747	0.000	0.000
Depressurization with fan on medium (Speed 2)	10/5/10 17:50	NR	-4.98	0.000 to 0.747 (door closed) -0.747 (door open)	-0.498 to -0.747
Depressurization with fan on medium (Speed 2)	10/6/10 17:40	NR	-2.988	0.000 to +0.498 (door closed) -0.498 (door open)	-0.747
Pressurization with fan on medium (Speed 2)	10/6/10 18:00	NR	+1.494	0.000 (door closed) +0.498 (door open)	+0.498
Pressurization with fan on medium (Speed 2)	10/7/10 17:53	NR	+1.743	0.000 (door closed) -0.498 (door open)	0.000 to +0.498

Notes:
1. Hand recorded readings from pressure transducer.
2. NR = not recorded

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TABLE A.6.11
ASU HOUSE HAPSITE RESULTS

ESTCP Tier 2 Vapor Screening Study

Samples Collected Under Stairs, October 4 - 7, 2010

Sample Date	Sample Time	Pressure Condition	DCE11	TCE
			ppbV	ppbV
10/1/2010	1:38	Baseline (Uncontrolled) Pressure	U	2.646
10/1/2010	3:38	Baseline (Uncontrolled) Pressure	U	1.805
10/1/2010	5:38	Baseline (Uncontrolled) Pressure	U	1.529
10/1/2010	7:39	Baseline (Uncontrolled) Pressure	U	2.259
10/1/2010	9:41	Baseline (Uncontrolled) Pressure	U	1.956
10/1/2010	9:49	Baseline (Uncontrolled) Pressure	U	1.820
10/1/2010	11:49	Baseline (Uncontrolled) Pressure	U	1.378
10/1/2010	13:50	Baseline (Uncontrolled) Pressure	U	1.054
10/1/2010	15:50	Baseline (Uncontrolled) Pressure	U	1.285
10/1/2010	17:50	Baseline (Uncontrolled) Pressure	0.088	0.521
10/1/2010	19:50	Baseline (Uncontrolled) Pressure	0.067	0.481
10/1/2010	21:52	Baseline (Uncontrolled) Pressure	0.072	0.632
10/1/2010	23:52	Baseline (Uncontrolled) Pressure	U	0.734
10/2/2010	1:53	Baseline (Uncontrolled) Pressure	0.046	1.044
10/2/2010	3:53	Baseline (Uncontrolled) Pressure	U	0.913
10/2/2010	5:53	Baseline (Uncontrolled) Pressure	U	1.080
10/2/2010	7:53	Baseline (Uncontrolled) Pressure	U	1.767
10/2/2010	9:55	Baseline (Uncontrolled) Pressure	U	1.925
10/2/2010	11:56	Baseline (Uncontrolled) Pressure	U	1.448
10/2/2010	13:56	Baseline (Uncontrolled) Pressure	U	1.862
10/2/2010	15:56	Baseline (Uncontrolled) Pressure	U	1.938
10/2/2010	17:56	Induced Negative Pressure	0.379	1.233
10/2/2010	19:57	Induced Negative Pressure	0.351	1.013
10/2/2010	21:58	Induced Negative Pressure	0.470	1.240
10/2/2010	23:59	Induced Negative Pressure	0.322	0.888
10/3/2010	1:59	Induced Negative Pressure	0.317	0.816
10/3/2010	3:59	Induced Negative Pressure	0.360	0.874
10/3/2010	5:59	Induced Negative Pressure	0.308	0.823
10/3/2010	8:00	Induced Negative Pressure	0.251	0.875
10/3/2010	10:02	Induced Negative Pressure	0.370	1.073
10/3/2010	12:02	Induced Negative Pressure	0.814	1.811
10/3/2010	14:02	Induced Negative Pressure	0.581	1.426
10/3/2010	16:02	Induced Positive Pressure	0.224	0.501
10/3/2010	18:03	Induced Positive Pressure	U	0.067
10/3/2010	20:03	Induced Positive Pressure	U	0.023
10/3/2010	22:05	Induced Positive Pressure	U	0.064
10/4/2010	0:05	Induced Positive Pressure	U	0.036
10/4/2010	2:05	Induced Positive Pressure	U	U
10/4/2010	4:05	Induced Positive Pressure	U	U
10/4/2010	6:06	Induced Positive Pressure	U	U
10/4/2010	8:06	Induced Positive Pressure	U	0.090
10/4/2010	11:32	Induced Positive Pressure	U	0.051
10/4/2010	12:32	Induced Positive Pressure	U	U
10/4/2010	13:33	Induced Positive Pressure	U	0.055
10/4/2010	14:33	Induced Positive Pressure	U	0.037
10/4/2010	15:33	Induced Positive Pressure	U	0.037
10/4/2010	16:33	Baseline (Uncontrolled) Pressure	U	U
10/4/2010	17:34	Baseline (Uncontrolled) Pressure	0.179	18.330
10/4/2010	18:34	Baseline (Uncontrolled) Pressure	0.202	15.250
10/4/2010	19:34	Baseline (Uncontrolled) Pressure	0.103	8.914
10/4/2010	20:34	Baseline (Uncontrolled) Pressure	U	7.099
10/4/2010	21:35	Baseline (Uncontrolled) Pressure	U	5.683
10/4/2010	22:37	Baseline (Uncontrolled) Pressure	U	5.321
10/4/2010	23:37	Baseline (Uncontrolled) Pressure	U	4.434
10/5/2010	0:37	Baseline (Uncontrolled) Pressure	U	2.448
10/5/2010	1:37	Baseline (Uncontrolled) Pressure	U	2.234
10/5/2010	2:38	Baseline (Uncontrolled) Pressure	U	2.078
10/5/2010	3:38	Baseline (Uncontrolled) Pressure	U	2.012
10/5/2010	4:38	Baseline (Uncontrolled) Pressure	U	1.883
10/5/2010	5:38	Baseline (Uncontrolled) Pressure	U	1.741
10/5/2010	6:38	Baseline (Uncontrolled) Pressure	U	1.694
10/5/2010	7:39	Baseline (Uncontrolled) Pressure	U	1.705
10/5/2010	8:39	Baseline (Uncontrolled) Pressure	U	1.602
10/5/2010	9:25	Baseline (Uncontrolled) Pressure	U	1.749
10/5/2010	10:26	Baseline (Uncontrolled) Pressure	0.052	7.657
10/5/2010	11:28	Baseline (Uncontrolled) Pressure	0.064	10.620
10/5/2010	11:49	Baseline (Uncontrolled) Pressure	0.063	9.590
10/5/2010	12:49	Baseline (Uncontrolled) Pressure	0.053	7.831
10/5/2010	13:50	Baseline (Uncontrolled) Pressure	0.052	7.290
10/5/2010	14:50	Baseline (Uncontrolled) Pressure	0.047	5.266
10/5/2010	15:50	Baseline (Uncontrolled) Pressure	U	4.465
10/5/2010	16:50	Baseline (Uncontrolled) Pressure	U	3.930

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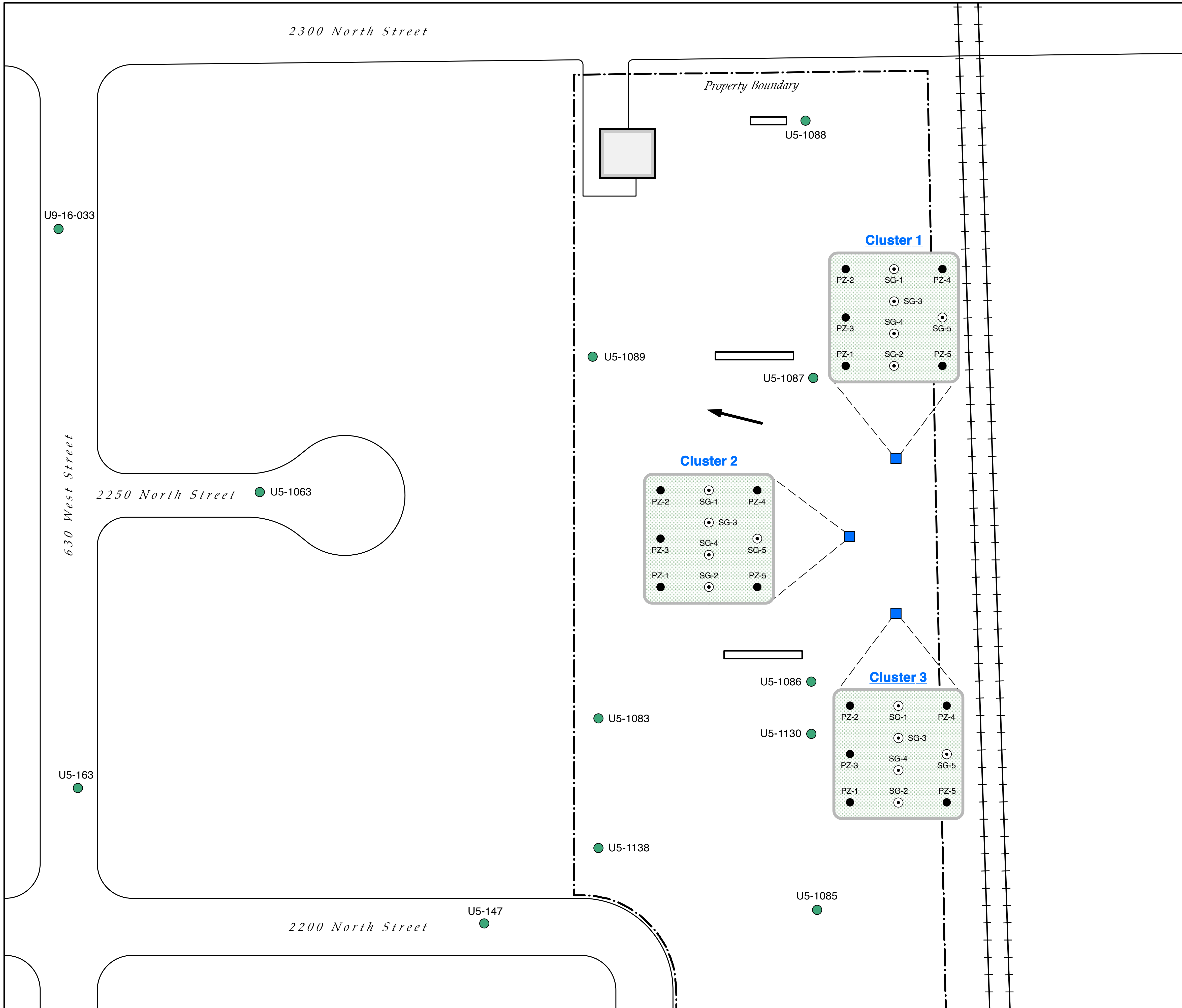
TABLE A.6.11
ASU HOUSE HAPSITE RESULTS

ESTCP Tier 2 Vapor Screening Study

Samples Collected Under Stairs, October 4 - 7, 2010

Sample Date	Sample Time	Pressure Condition	DCE11	TCE
			ppbV	ppbV
10/5/2010	17:51	Induced Negative Pressure	U	2.557
10/5/2010	18:51	Induced Negative Pressure	1.403	2.543
10/5/2010	19:51	Induced Negative Pressure	0.978	1.944
10/5/2010	20:51	Induced Negative Pressure	0.170	0.513
10/5/2010	21:52	Induced Negative Pressure	0.129	0.515
10/5/2010	22:52	Induced Negative Pressure	0.149	0.574
10/5/2010	23:54	Induced Negative Pressure	0.205	0.707
10/6/2010	0:54	Induced Negative Pressure	0.207	0.685
10/6/2010	1:54	Induced Negative Pressure	0.206	0.677
10/6/2010	2:55	Induced Negative Pressure	0.169	0.596
10/6/2010	3:55	Induced Negative Pressure	0.218	0.630
10/6/2010	4:55	Induced Negative Pressure	0.240	0.653
10/6/2010	5:55	Induced Negative Pressure	0.186	0.616
10/6/2010	6:56	Induced Negative Pressure	0.193	0.623
10/6/2010	7:56	Induced Negative Pressure	0.217	0.664
10/6/2010	8:56	Induced Negative Pressure	0.169	0.640
10/6/2010	9:56	Induced Negative Pressure	0.243	0.688
10/6/2010	10:58	Induced Negative Pressure	0.664	1.430
10/6/2010	12:00	Induced Negative Pressure	1.861	3.548
10/6/2010	13:00	Induced Negative Pressure	0.703	1.756
10/6/2010	14:00	Induced Negative Pressure	1.895	3.618
10/6/2010	15:00	Induced Negative Pressure	0.854	1.936
10/6/2010	16:01	Induced Negative Pressure	0.638	1.453
10/6/2010	17:01	Induced Negative Pressure	0.392	0.912
10/6/2010	18:01	Induced Positive Pressure	0.466	1.063
10/6/2010	19:01	Induced Positive Pressure	0.046	0.122
10/6/2010	20:02	Induced Positive Pressure	U	0.069
10/6/2010	21:02	Induced Positive Pressure	U	0.065
10/6/2010	22:02	Induced Positive Pressure	U	0.059
10/6/2010	23:02	Induced Positive Pressure	U	0.048
10/7/2010	0:04	Induced Positive Pressure	U	0.053
10/7/2010	1:05	Induced Positive Pressure	U	0.056
10/7/2010	2:05	Induced Positive Pressure	U	0.048
10/7/2010	3:05	Induced Positive Pressure	U	0.048
10/7/2010	4:05	Induced Positive Pressure	0.046	0.047
10/7/2010	5:06	Induced Positive Pressure	U	0.050
10/7/2010	6:06	Induced Positive Pressure	U	0.031
10/7/2010	7:06	Induced Positive Pressure	U	0.040
10/7/2010	8:06	Induced Positive Pressure	U	0.031
10/7/2010	9:06	Induced Positive Pressure	U	0.028
10/7/2010	10:07	Induced Positive Pressure	U	0.027
10/7/2010	11:07	Induced Positive Pressure	U	0.025
10/7/2010	12:09	Induced Positive Pressure	0.066	U
10/7/2010	13:09	Induced Positive Pressure	U	U
10/7/2010	14:09	Induced Positive Pressure	U	0.039
10/7/2010	15:05	Induced Positive Pressure	U	U
10/7/2010	16:05	Induced Positive Pressure	U	0.052
10/7/2010	17:05	Induced Positive Pressure	U	U
10/7/2010	18:05	Baseline (Uncontrolled) Pressure	U	0.060
10/7/2010	19:06	Baseline (Uncontrolled) Pressure	U	0.161
10/7/2010	20:06	Baseline (Uncontrolled) Pressure	U	0.208
10/7/2010	21:06	Baseline (Uncontrolled) Pressure	U	0.778
10/7/2010	22:06	Baseline (Uncontrolled) Pressure	U	0.736
10/7/2010	23:07	Baseline (Uncontrolled) Pressure	U	0.785

Notes:
1. U = compound not quantified



N

LEGEND

- Groundwater sampling location (1-in piezometer)
- Soil gas sampling location
- Existing monitoring well location
- Approximate direction of groundwater flow
- OU5 property boundary line

Note:
1) Scale of cluster insets 1in = 3 ft.

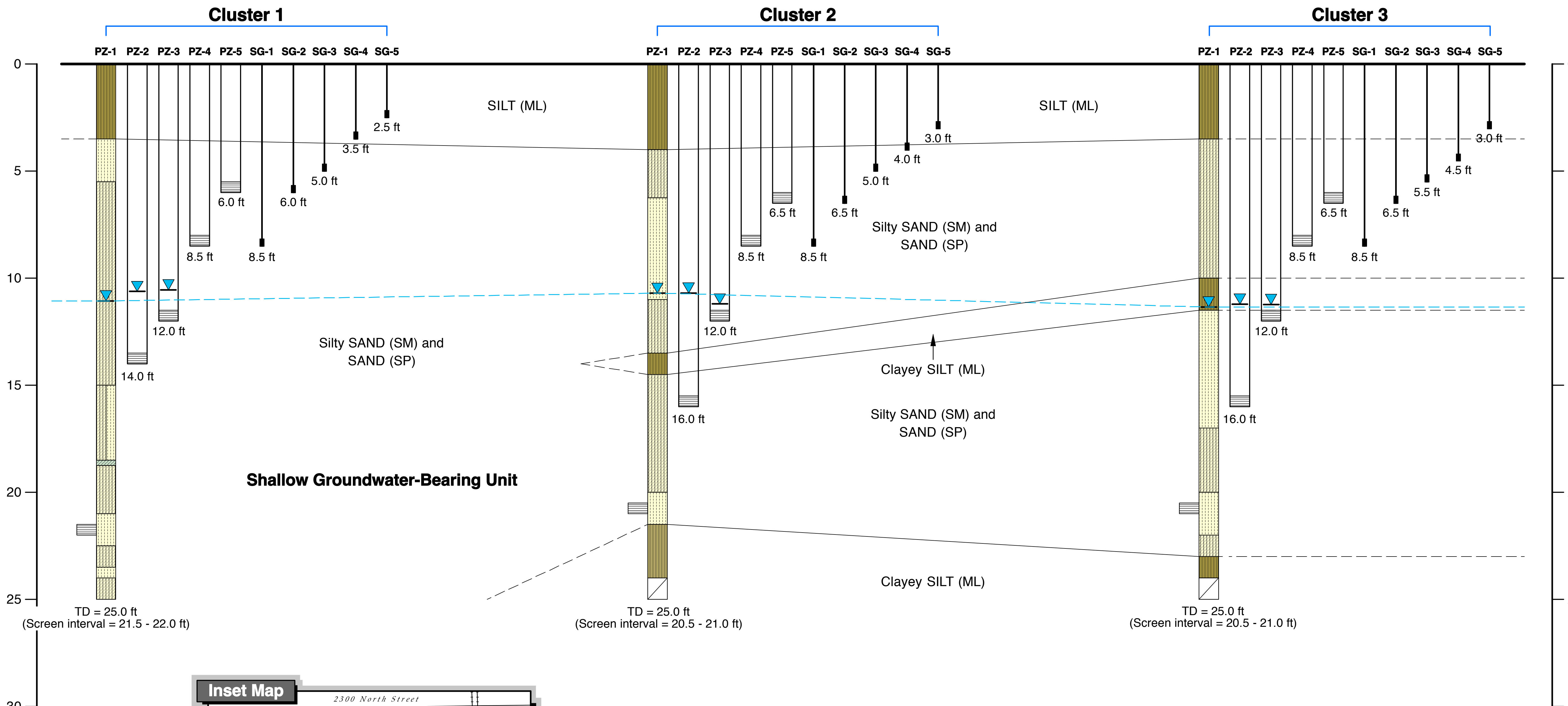
SCALE (ft.)
0 50 100

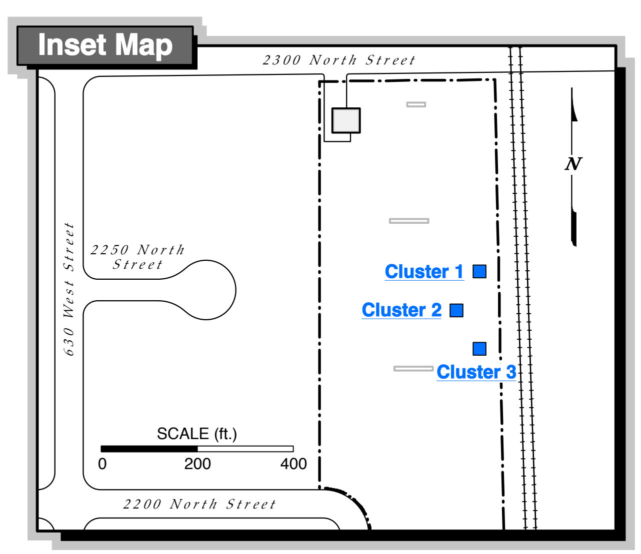
GSI ENVIRONMENTAL

GROUNDWATER AND SOIL GAS SAMPLING LOCATIONS

ESTCP Tier 2 Vapor Screening Study
Operable Unit 5 Property, Hill Air Force Base, Clinton, Utah

GSI Job No:	G-3213	Drawn By:	DLB
Issued:	18-Nov-11	Chk'd By:	DMB
Revised:	———	Appv'd By:	DMB
Scale:	As Shown	**FIGURE A.6.1**	





LEGEND

- Silty SAND (SM)
- SAND (SP)
- Silty CLAY (CL)
- Clayey SILT (ML)
- No Recovery
- Screen interval
- Static water level, as measured on 26-Aug-11
- Potentiometric surface based on static water levels measured on 26-Aug-11

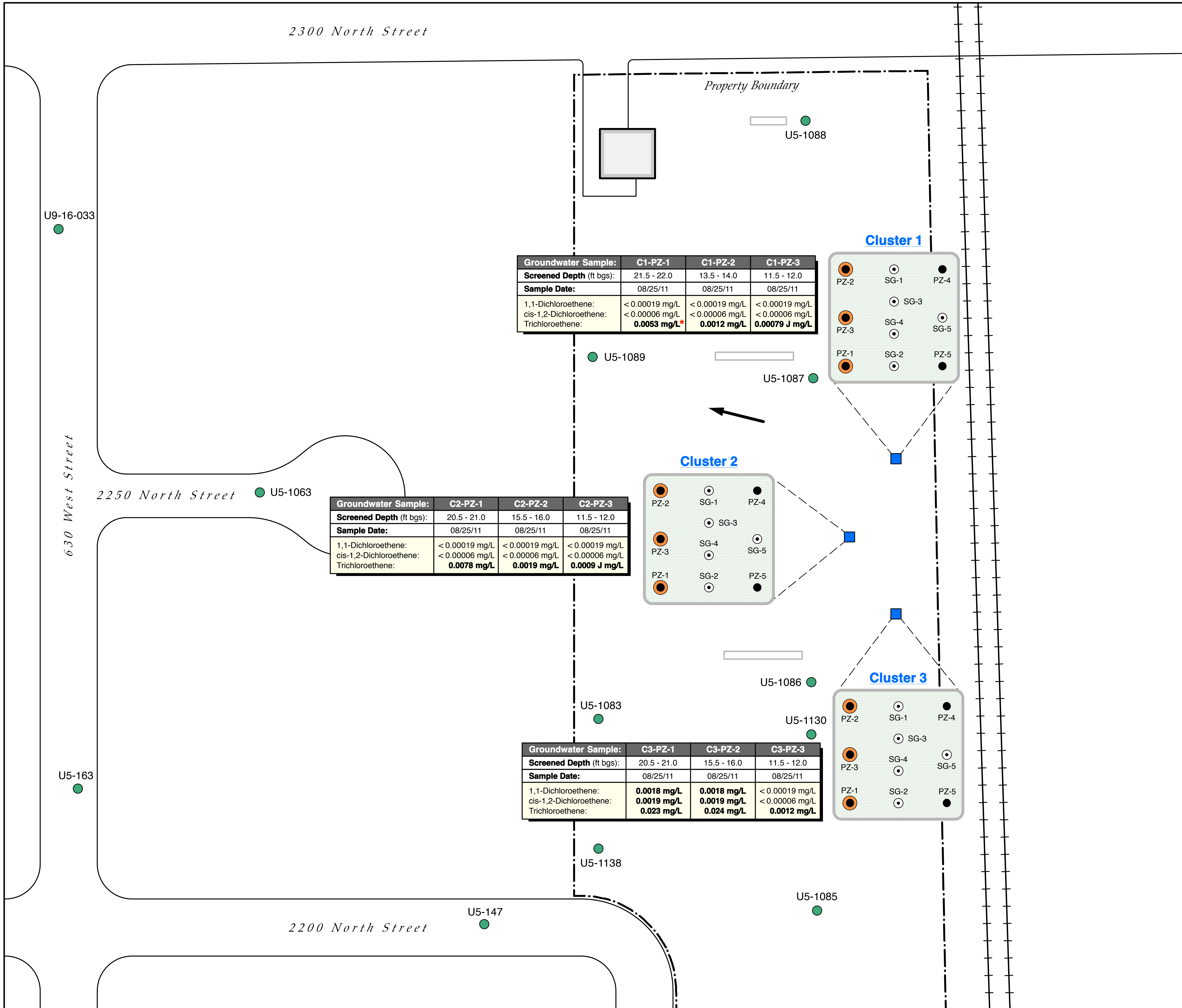
Note: To illustrate the entire lithology at C1-PZ-1, C2-PZ-1, and C3-PZ-1, the screen interval is presented adjacent to the lithology.

GSI ENVIRONMENTAL

CONCEPTUAL CROSS-SECTION OF SUBSURFACE SAMPLE POINTS AND SHALLOW GEOLOGY

ESTCP Tier 2 Vapor Screening Study
Operable Unit 5 Property, Hill Air Force Base, Clinton, Utah

GSI Job No:	G-3213	Drawn By:	DLB
Issued:	18-Nov-11	Chk'd By:	DMB
Revised:	———	Appv'd By:	DMB
Scale:	As Shown		**FIGURE A.6.2**



Groundwater Sample:	C1-PZ-1	C1-PZ-2	C1-PZ-3
Screened Depth (ft bgs):	21.5 - 22.0	13.5 - 14.0	11.5 - 12.0
Sample Date:	08/25/11	08/25/11	08/25/11
1,1-Dichloroethene:	< 0.00019 mg/L	< 0.00019 mg/L	< 0.00019 mg/L
cis-1,2-Dichloroethene:	< 0.00006 mg/L	< 0.00006 mg/L	< 0.00006 mg/L
Trichloroethene:	**0.0053 mg/L***	**0.0012 mg/L**	**0.00079 J mg/L**

Groundwater Sample:	C2-PZ-1	C2-PZ-2	C2-PZ-3
Screened Depth (ft bgs):	20.5 - 21.0	15.5 - 16.0	11.5 - 12.0
Sample Date:	08/25/11	08/25/11	08/25/11
1,1-Dichloroethene:	< 0.00019 mg/L	< 0.00019 mg/L	< 0.00019 mg/L
cis-1,2-Dichloroethene:	< 0.00006 mg/L	< 0.00006 mg/L	< 0.00006 mg/L
Trichloroethene:	**0.0078 mg/L**	**0.0019 mg/L**	**0.0009 J mg/L**

Groundwater Sample:	C3-PZ-1	C3-PZ-2	C3-PZ-3
Screened Depth (ft bgs):	20.5 - 21.0	15.5 - 16.0	11.5 - 12.0
Sample Date:	08/25/11	08/25/11	08/25/11
1,1-Dichloroethene:	**0.0018 mg/L**	**0.0018 mg/L**	< 0.00019 mg/L
cis-1,2-Dichloroethene:	**0.0019 mg/L**	**0.0019 mg/L**	< 0.00006 mg/L
Trichloroethene:	**0.023 mg/L**	**0.024 mg/L**	**0.0012 mg/L**

LEGEND

- Groundwater sampling location (1-in piezometer)
- Soil gas sampling location
- Existing monitoring well location
- One or more COCs detected above the reporting limit
- COCs not detected
- * Duplicate samples taken; average value shown
- Approximate direction of groundwater flow

Notes:

1) COC = Constituent of Concern (i.e., TCE, 1,1-DCE and cis-1,2-DCE)
2) Groundwater samples were analyzed by TestAmerica Laboratories Inc. in Houston, Texas.
3) TCE = Trichloroethene
cis-1,2-DCE = cis-1,2-Dichloroethene
1,1-DCE = 1,1-Dichloroethene
bgs = Below ground surface
4) Scale of cluster insets 1in = 3 ft.

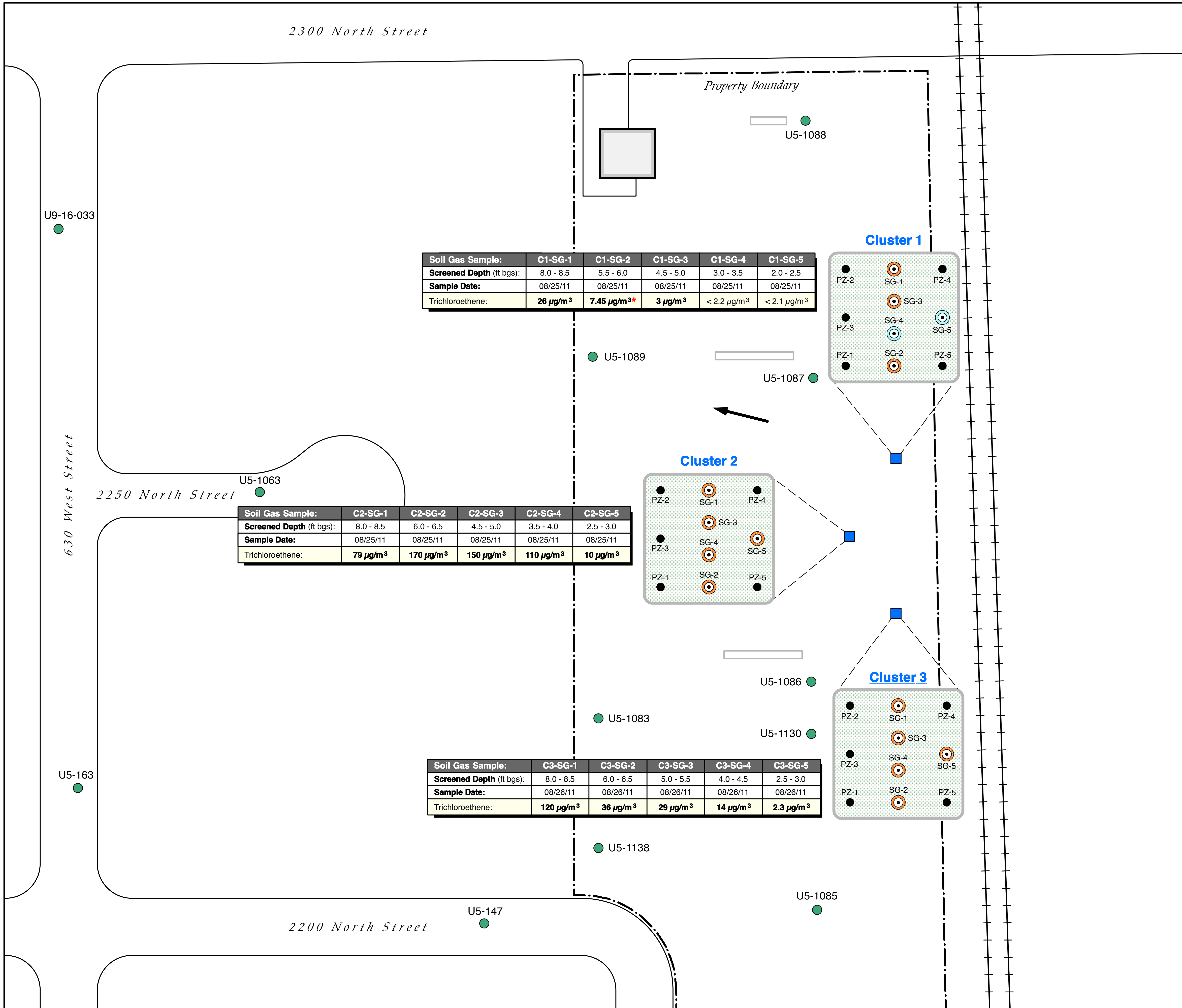
SCALE (ft.)
0 50 100

GSI ENVIRONMENTAL

GROUNDWATER SAMPLING AND TESTING RESULTS

ESTCP Tier 2 Vapor Screening Study
Operable Unit 5 Property, Hill Air Force Base, Clinton, Utah

GSI Job No:	G-3213	Drawn By:	DLB
Issued:	18-Nov-11	Chk'd By:	DMB
Revised:	———	Appv'd By:	DMB
Scale:	As Shown		**FIGURE A.6.3**



Soil Gas Sample:	C1-SG-1	C1-SG-2	C1-SG-3	C1-SG-4	C1-SG-5
Screened Depth (ft bgs):	8.0 - 8.5	5.5 - 6.0	4.5 - 5.0	3.0 - 3.5	2.0 - 2.5
Sample Date:	08/25/11	08/25/11	08/25/11	08/25/11	08/25/11
Trichloroethene:	**26 μg/m³**	**7.45 μg/m³***	**3 μg/m³**	< 2.2 μg/m³	< 2.1 μg/m³

Soil Gas Sample:	C2-SG-1	C2-SG-2	C2-SG-3	C2-SG-4	C2-SG-5
Screened Depth (ft bgs):	8.0 - 8.5	6.0 - 6.5	4.5 - 5.0	3.5 - 4.0	2.5 - 3.0
Sample Date:	08/25/11	08/25/11	08/25/11	08/25/11	08/25/11
Trichloroethene:	**79 μg/m³**	**170 μg/m³**	**150 μg/m³**	**110 μg/m³**	**10 μg/m³**

Soil Gas Sample:	C3-SG-1	C3-SG-2	C3-SG-3	C3-SG-4	C3-SG-5
Screened Depth (ft bgs):	8.0 - 8.5	6.0 - 6.5	5.0 - 5.5	4.0 - 4.5	2.5 - 3.0
Sample Date:	08/26/11	08/26/11	08/26/11	08/26/11	08/26/11
Trichloroethene:	**120 μg/m³**	**36 μg/m³**	**29 μg/m³**	**14 μg/m³**	**2.3 μg/m³**

N

LEGEND

- Groundwater sampling location (1-in piezometer)
- Soil gas sampling location
- Existing monitoring well location
- One or more COCs detected above the reporting limit
- COCs not detected
- * Duplicate samples taken; average value shown
- Approximate direction of groundwater flow

Notes:

1) COC = Constituent of Concern (i.e., TCE)
2) Soil gas samples were analyzed by Columbia Analytical Services in Simi Valley, California.
3) TCE = Trichloroethene
   bgs = Below ground surface
4) Scale of cluster insets 1in = 3 ft.

SCALE (ft.)
0 50 100

GSI ENVIRONMENTAL

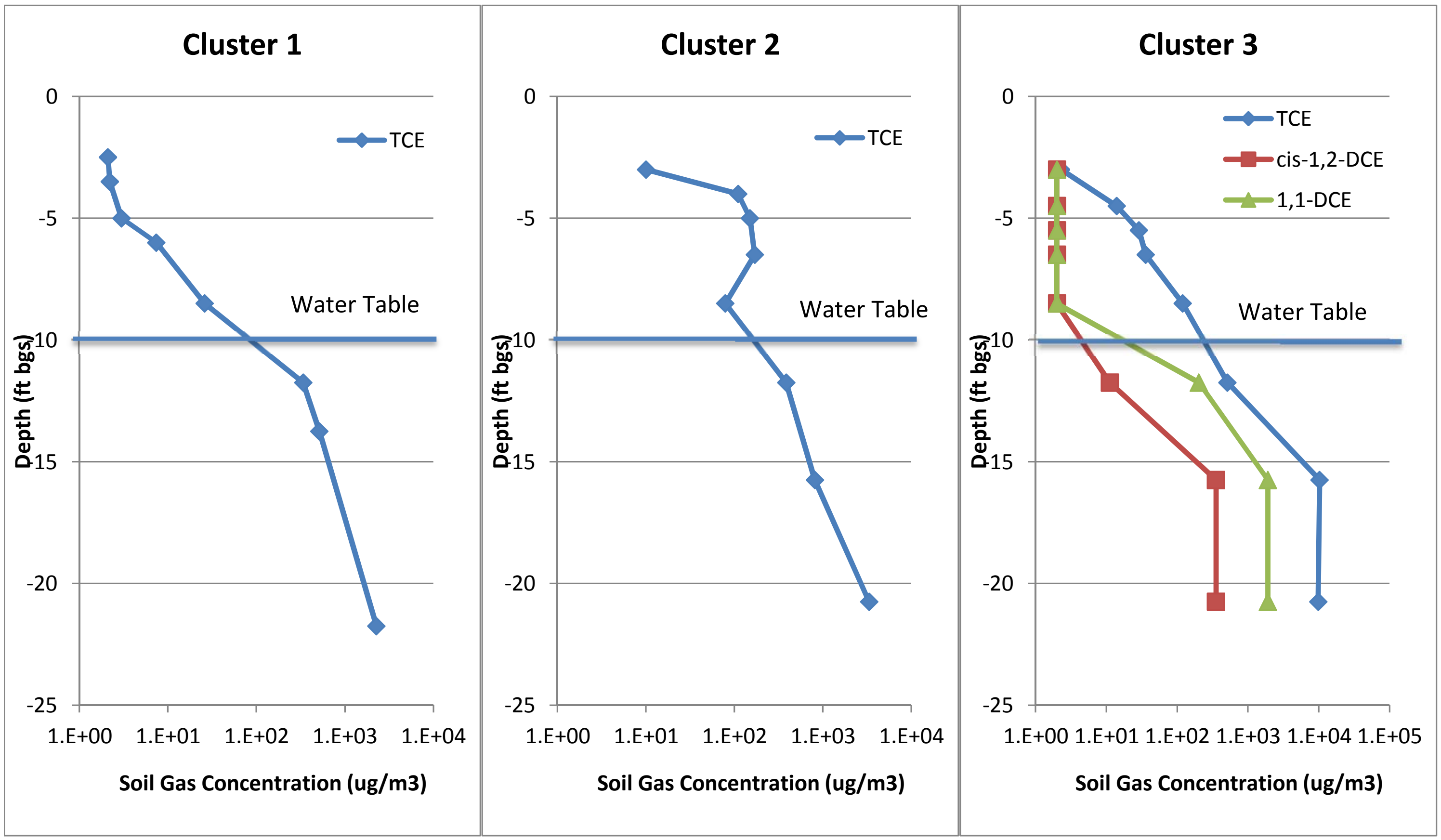
SOIL GAS SAMPLING AND TESTING RESULTS

ESTCP Tier 2 Vapor Screening Study
Operable Unit 5 Property, Hill Air Force Base, Clinton, Utah

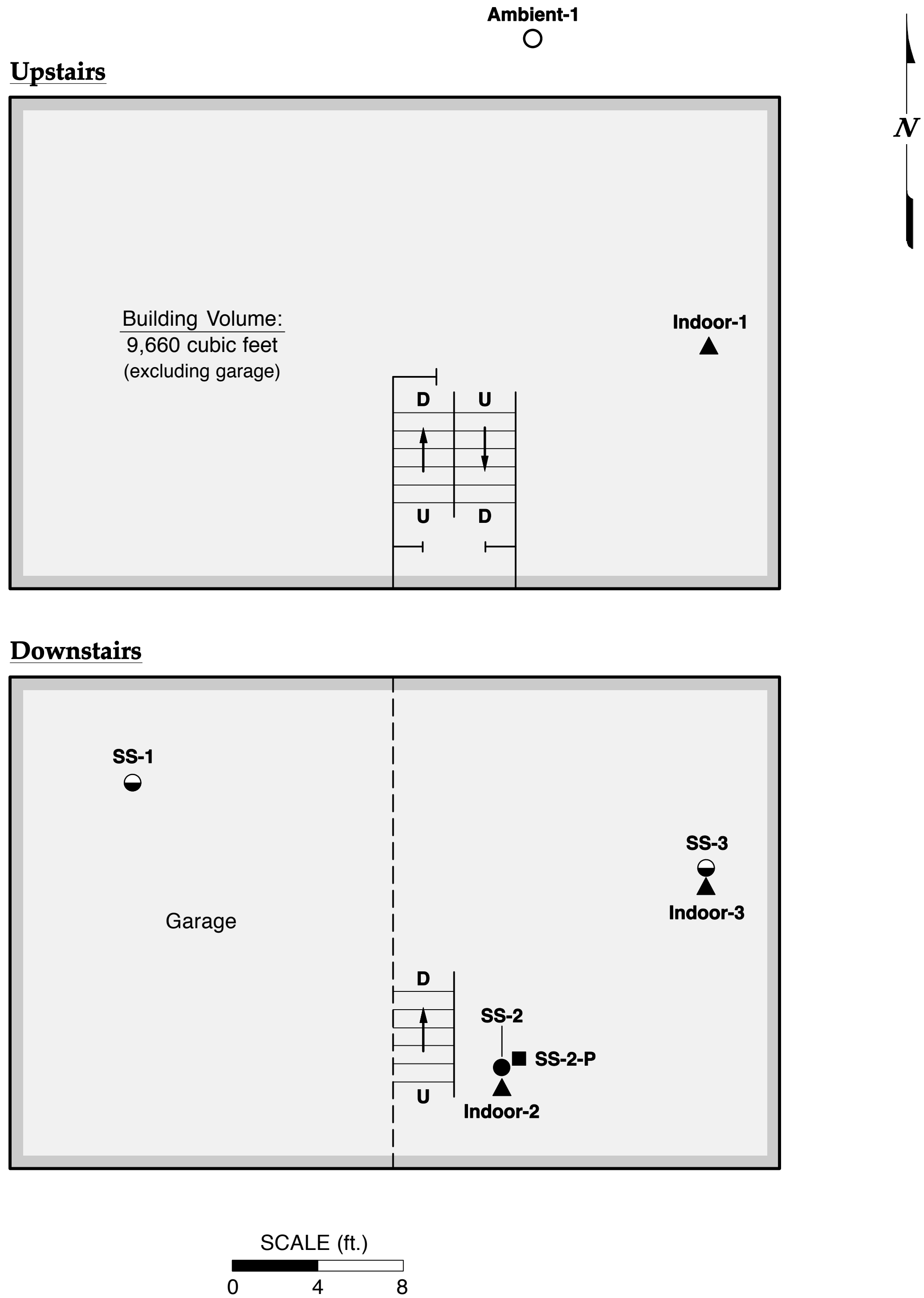
GSI Job No:	G-3213	Drawn By:	DLB
Issued:	18-Nov-11	Chk'd By:	DMB
Revised:	——	Appv'd By:	DMB
Scale:	As Shown		**FIGURE A.6.4**

GSI Job No. G-3213
Issued: 18 November 2011

FIGURE A.6.5
VERTICAL VOC PROFILE
ESTCP Tier 2 Vapor Screening Study
Hill AFB, Utah



* = Concentrations in groundwater (i.e., below the water table) were converted into equivalent soil gas concentrations using Henry's Law assuming equilibrium partitioning.



LEGEND

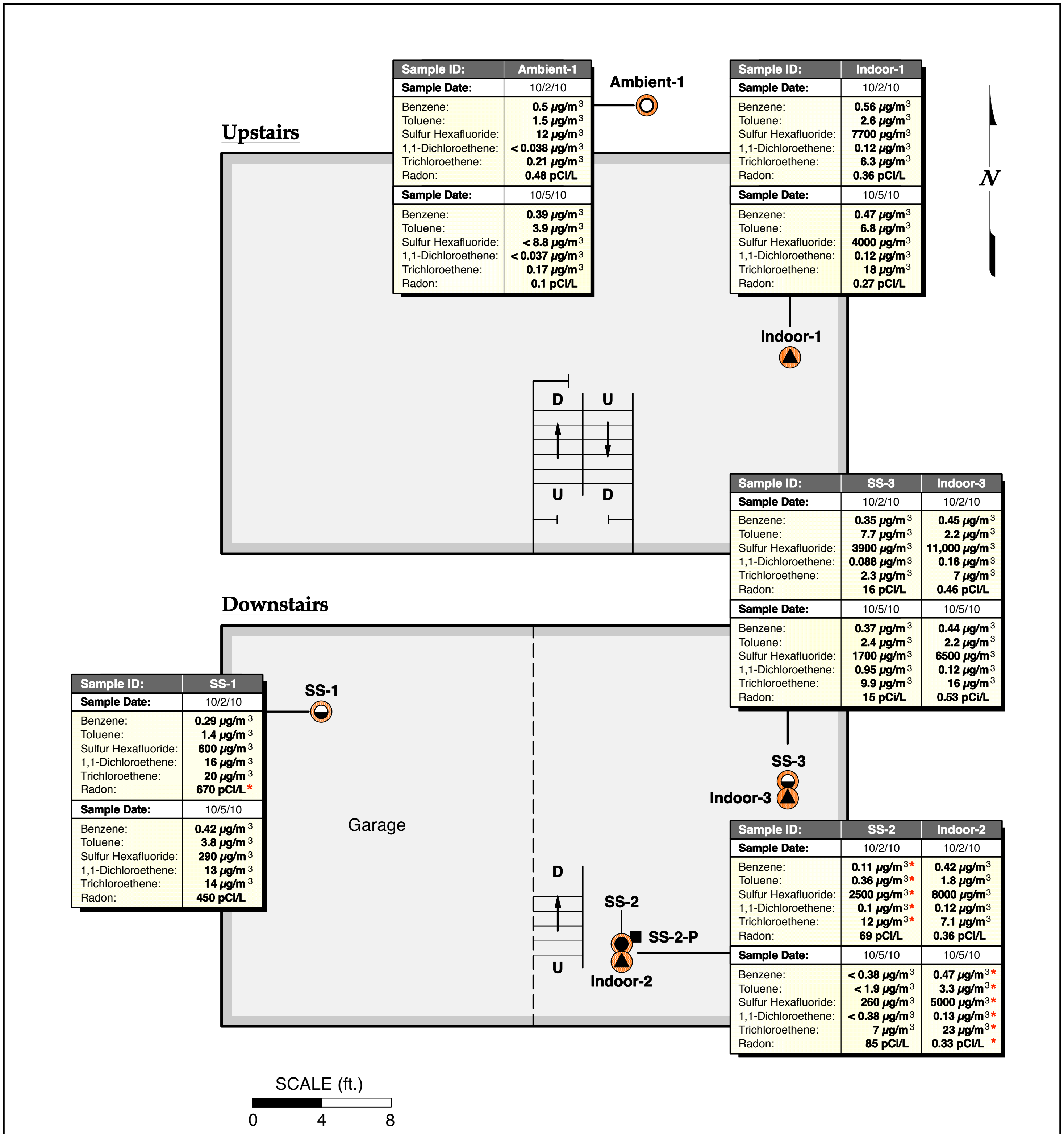
- ● Sub-slab sampling point
- ◒ Both sub-slab and pressure measurement point
- ■ Pressure measurement point
- ○ Ambient air sampling location
- ▲ Indoor air sampling location

GSI ENVIRONMENTAL

SUB-SLAB, INDOOR AND AMBIENT AIR SAMPLING AND MEASUREMENT LOCATIONS

ESTCP Tier 2 Vapor Screening Study
ASU Research House, Layton, Utah

GSI Job No:	G-3213	Drawn By:	DLB
Issued:	18-Nov-11	Chk'd By:	LMB
Revised:	———	Appv'd By:	LMB
Scale:	As Shown		**FIGURE A.6.6**



Sample ID:	Ambient-1
Sample Date:	10/2/10
Benzene:	**0.5 μg/m³**
Toluene:	**1.5 μg/m³**
Sulfur Hexafluoride:	**12 μg/m³**
1,1-Dichloroethene:	**< 0.038 μg/m³**
Trichloroethene:	**0.21 μg/m³**
Radon:	**0.48 pCi/L**
Sample Date:	10/5/10
Benzene:	**0.39 μg/m³**
Toluene:	**3.9 μg/m³**
Sulfur Hexafluoride:	**< 8.8 μg/m³**
1,1-Dichloroethene:	**< 0.037 μg/m³**
Trichloroethene:	**0.17 μg/m³**
Radon:	**0.1 pCi/L**

Sample ID:	Indoor-1
Sample Date:	10/2/10
Benzene:	**0.56 μg/m³**
Toluene:	**2.6 μg/m³**
Sulfur Hexafluoride:	**7700 μg/m³**
1,1-Dichloroethene:	**0.12 μg/m³**
Trichloroethene:	**6.3 μg/m³**
Radon:	**0.36 pCi/L**
Sample Date:	10/5/10
Benzene:	**0.47 μg/m³**
Toluene:	**6.8 μg/m³**
Sulfur Hexafluoride:	**4000 μg/m³**
1,1-Dichloroethene:	**0.12 μg/m³**
Trichloroethene:	**18 μg/m³**
Radon:	**0.27 pCi/L**

Sample ID:	SS-3	Indoor-3
Sample Date:	10/2/10	10/2/10
Benzene:	**0.35 μg/m³**	**0.45 μg/m³**
Toluene:	**7.7 μg/m³**	**2.2 μg/m³**
Sulfur Hexafluoride:	**3900 μg/m³**	**11,000 μg/m³**
1,1-Dichloroethene:	**0.088 μg/m³**	**0.16 μg/m³**
Trichloroethene:	**2.3 μg/m³**	**7 μg/m³**
Radon:	**16 pCi/L**	**0.46 pCi/L**
Sample Date:	10/5/10	10/5/10
Benzene:	**0.37 μg/m³**	**0.44 μg/m³**
Toluene:	**2.4 μg/m³**	**2.2 μg/m³**
Sulfur Hexafluoride:	**1700 μg/m³**	**6500 μg/m³**
1,1-Dichloroethene:	**0.95 μg/m³**	**0.12 μg/m³**
Trichloroethene:	**9.9 μg/m³**	**16 μg/m³**
Radon:	**15 pCi/L**	**0.53 pCi/L**

Sample ID:	SS-1
Sample Date:	10/2/10
Benzene:	**0.29 μg/m³**
Toluene:	**1.4 μg/m³**
Sulfur Hexafluoride:	**600 μg/m³**
1,1-Dichloroethene:	**16 μg/m³**
Trichloroethene:	**20 μg/m³**
Radon:	**670 pCi/L** *
Sample Date:	10/5/10
Benzene:	**0.42 μg/m³**
Toluene:	**3.8 μg/m³**
Sulfur Hexafluoride:	**290 μg/m³**
1,1-Dichloroethene:	**13 μg/m³**
Trichloroethene:	**14 μg/m³**
Radon:	**450 pCi/L**

Sample ID:	SS-2	Indoor-2
Sample Date:	10/2/10	10/2/10
Benzene:	**0.11 μg/m³** *	**0.42 μg/m³**
Toluene:	**0.36 μg/m³** *	**1.8 μg/m³**
Sulfur Hexafluoride:	**2500 μg/m³** *	**8000 μg/m³**
1,1-Dichloroethene:	**0.1 μg/m³** *	**0.12 μg/m³**
Trichloroethene:	**12 μg/m³** *	**7.1 μg/m³**
Radon:	**69 pCi/L**	**0.36 pCi/L**
Sample Date:	10/5/10	10/5/10
Benzene:	**< 0.38 μg/m³**	**0.47 μg/m³** *
Toluene:	**< 1.9 μg/m³**	**3.3 μg/m³** *
Sulfur Hexafluoride:	**260 μg/m³**	**5000 μg/m³** *
1,1-Dichloroethene:	**< 0.38 μg/m³**	**0.13 μg/m³** *
Trichloroethene:	**7 μg/m³**	**23 μg/m³** *
Radon:	**85 pCi/L**	**0.33 pCi/L** *

LEGEND

- ● Sub-slab sampling point
- ■ Pressure measurement point
- ◒ Both sub-slab and pressure measurement point
- ○ Ambient air sampling location
- ▲ Indoor air sampling location
- One or more COCs detected above the reporting limit.
- COCs not detected
- * Duplicate samples taken; average value shown

Notes:

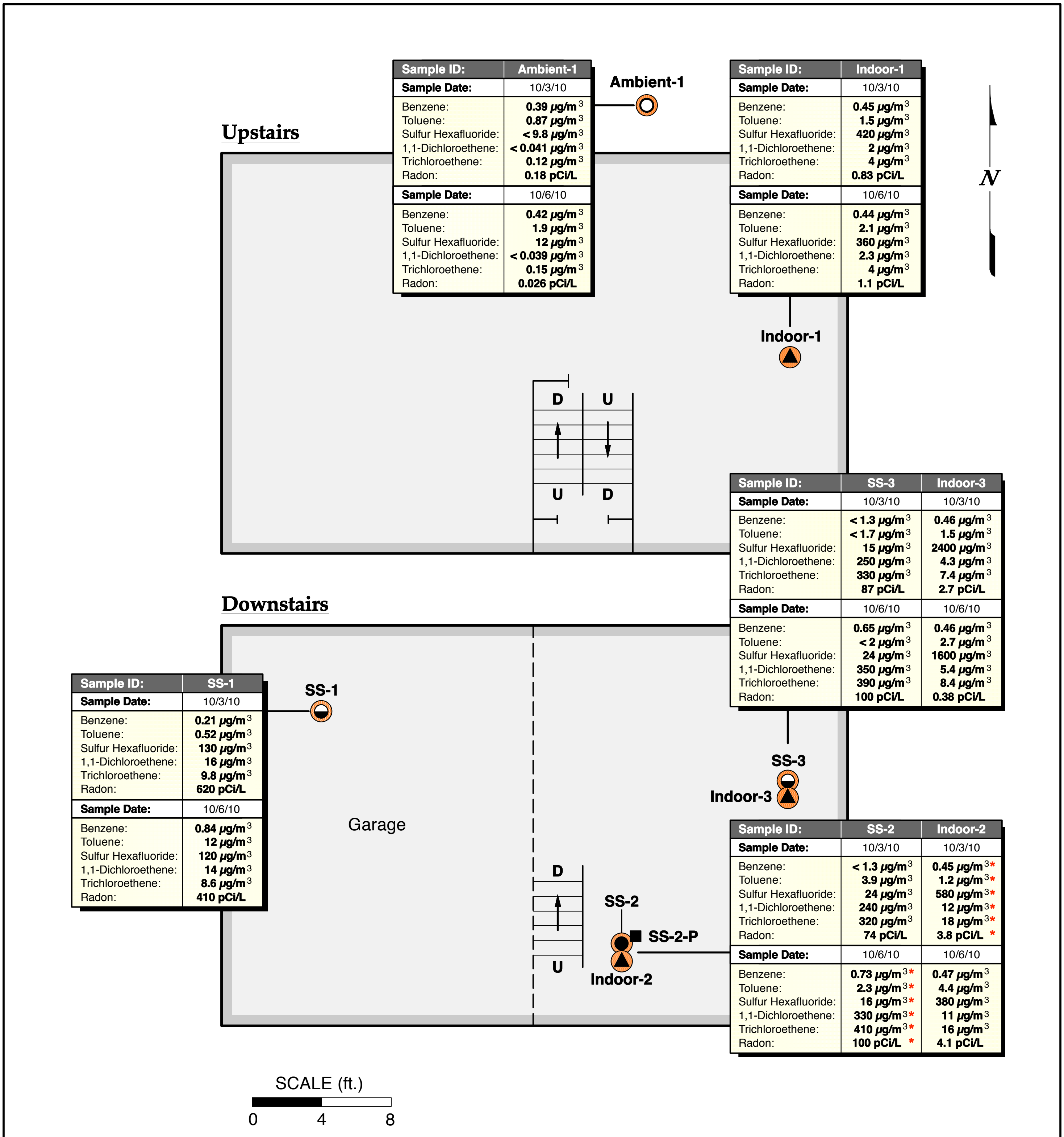
1) COC = Constituent of Concern. COCs include volatile organic compounds.
2) SF_6 and radon were used as tracer gases.
3) VOC and SF_6 analysis by Columbia Analytical Services, Inc. in Simi Valley, California. Radon analysis by USC except for Round 1 sub-slab measurements which were collected with RAD7 portable radon detector.
4) Indoor air samples were collected adjacent to the sub-slab location, except for Indoor-1.
5) Sub-slab samples, SS-1, SS-2, and SS-3 were collected 8 inches below the slab.
6) Results rounded to 2 significant figures.

GSI ENVIRONMENTAL

SUB-SLAB AND INDOOR AIR SAMPLING AND TESTING RESULTS: BASELINE

ESTCP Tier 2 Vapor Screening Study
ASU Research House, Layton, Utah

GSI Job No: G-3213	Drawn By: DLB
Issued: 18-Nov-11	Chk'd By: LMB
Revised: ————	Appv'd By: LMB
Scale: As Shown	**FIGURE A.6.7**



Sample ID:	Ambient-1
Sample Date:	10/3/10
Benzene:	**0.39 μg/m³**
Toluene:	**0.87 μg/m³**
Sulfur Hexafluoride:	**< 9.8 μg/m³**
1,1-Dichloroethene:	**< 0.041 μg/m³**
Trichloroethene:	**0.12 μg/m³**
Radon:	**0.18 pCi/L**
Sample Date:	10/6/10
Benzene:	**0.42 μg/m³**
Toluene:	**1.9 μg/m³**
Sulfur Hexafluoride:	**12 μg/m³**
1,1-Dichloroethene:	**< 0.039 μg/m³**
Trichloroethene:	**0.15 μg/m³**
Radon:	**0.026 pCi/L**

Sample ID:	Indoor-1
Sample Date:	10/3/10
Benzene:	**0.45 μg/m³**
Toluene:	**1.5 μg/m³**
Sulfur Hexafluoride:	**420 μg/m³**
1,1-Dichloroethene:	**2 μg/m³**
Trichloroethene:	**4 μg/m³**
Radon:	**0.83 pCi/L**
Sample Date:	10/6/10
Benzene:	**0.44 μg/m³**
Toluene:	**2.1 μg/m³**
Sulfur Hexafluoride:	**360 μg/m³**
1,1-Dichloroethene:	**2.3 μg/m³**
Trichloroethene:	**4 μg/m³**
Radon:	**1.1 pCi/L**

Sample ID:	SS-3	Indoor-3
Sample Date:	10/3/10	10/3/10
Benzene:	**< 1.3 μg/m³**	**0.46 μg/m³**
Toluene:	**< 1.7 μg/m³**	**1.5 μg/m³**
Sulfur Hexafluoride:	**15 μg/m³**	**2400 μg/m³**
1,1-Dichloroethene:	**250 μg/m³**	**4.3 μg/m³**
Trichloroethene:	**330 μg/m³**	**7.4 μg/m³**
Radon:	**87 pCi/L**	**2.7 pCi/L**
Sample Date:	10/6/10	10/6/10
Benzene:	**0.65 μg/m³**	**0.46 μg/m³**
Toluene:	**< 2 μg/m³**	**2.7 μg/m³**
Sulfur Hexafluoride:	**24 μg/m³**	**1600 μg/m³**
1,1-Dichloroethene:	**350 μg/m³**	**5.4 μg/m³**
Trichloroethene:	**390 μg/m³**	**8.4 μg/m³**
Radon:	**100 pCi/L**	**0.38 pCi/L**

Sample ID:	SS-1
Sample Date:	10/3/10
Benzene:	**0.21 μg/m³**
Toluene:	**0.52 μg/m³**
Sulfur Hexafluoride:	**130 μg/m³**
1,1-Dichloroethene:	**16 μg/m³**
Trichloroethene:	**9.8 μg/m³**
Radon:	**620 pCi/L**
Sample Date:	10/6/10
Benzene:	**0.84 μg/m³**
Toluene:	**12 μg/m³**
Sulfur Hexafluoride:	**120 μg/m³**
1,1-Dichloroethene:	**14 μg/m³**
Trichloroethene:	**8.6 μg/m³**
Radon:	**410 pCi/L**

Sample ID:	SS-2	Indoor-2
Sample Date:	10/3/10	10/3/10
Benzene:	**< 1.3 μg/m³**	**0.45 μg/m³***
Toluene:	**3.9 μg/m³**	**1.2 μg/m³***
Sulfur Hexafluoride:	**24 μg/m³**	**580 μg/m³***
1,1-Dichloroethene:	**240 μg/m³**	**12 μg/m³***
Trichloroethene:	**320 μg/m³**	**18 μg/m³***
Radon:	**74 pCi/L**	**3.8 pCi/L** *
Sample Date:	10/6/10	10/6/10
Benzene:	**0.73 μg/m³***	**0.47 μg/m³**
Toluene:	**2.3 μg/m³***	**4.4 μg/m³**
Sulfur Hexafluoride:	**16 μg/m³***	**380 μg/m³**
1,1-Dichloroethene:	**330 μg/m³***	**11 μg/m³**
Trichloroethene:	**410 μg/m³***	**16 μg/m³**
Radon:	**100 pCi/L** *	**4.1 pCi/L**

LEGEND

- Sub-slab sampling point
- Pressure measurement point
- Both sub-slab and pressure measurement point
- Ambient air sampling location
- Indoor air sampling location
- One or more COCs detected above the reporting limit.
- COCs not detected
- * Duplicate samples taken; average value shown

Notes:

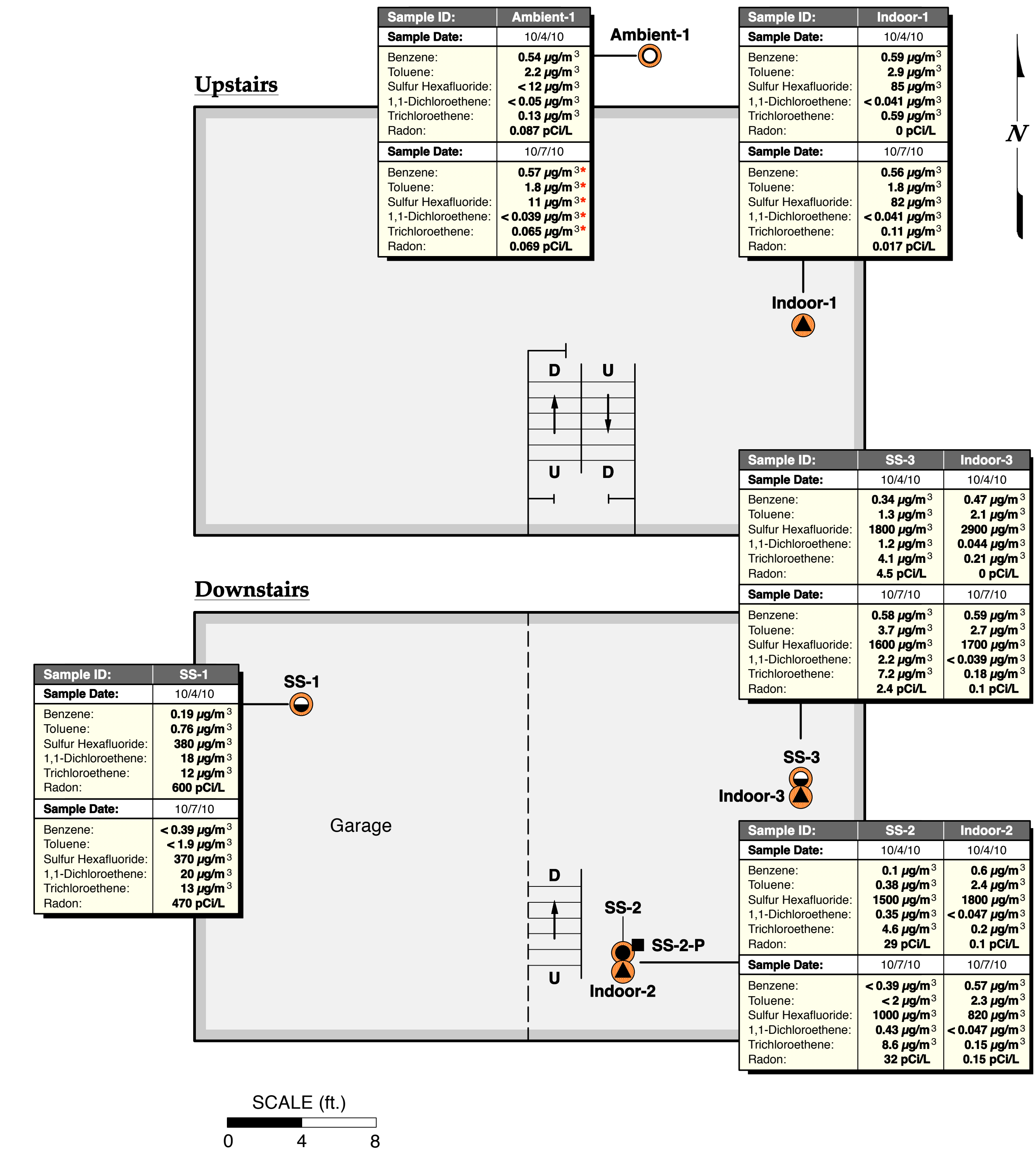
1) COC = Constituent of Concern. COCs include volatile organic compounds.
2) SF_6 and radon were used as tracer gases.
3) VOC and SF_6 analysis by Columbia Analytical Services, Inc. in Simi Valley, California. Radon analysis by USC except for Round 1 sub-slab measurements which were collected with RAD7 portable radon detector.
4) Indoor air samples were collected adjacent to the sub-slab location, except for Indoor-1.
5) Sub-slab samples, SS-1, SS-2, and SS-3 were collected 8 inches below the slab.
6) Results rounded to 2 significant figures.

GSI ENVIRONMENTAL

SUB-SLAB AND INDOOR AIR SAMPLING AND TESTING RESULTS: NEGATIVE PRESSURE

ESTCP Tier 2 Vapor Screening Study
ASU Research House, Layton, Utah

GSI Job No:	G-3213	Drawn By:	DLB
Issued:	18-Nov-11	Chk'd By:	LMB
Revised:	————	Appv'd By:	LMB
Scale:	As Shown		**FIGURE A.6.8**



Sample ID:	Ambient-1
Sample Date:	10/4/10
Benzene:	**0.54 µg/m³**
Toluene:	**2.2 µg/m³**
Sulfur Hexafluoride:	**< 12 µg/m³**
1,1-Dichloroethene:	**< 0.05 µg/m³**
Trichloroethene:	**0.13 µg/m³**
Radon:	**0.087 pCi/L**
Sample Date:	10/7/10
Benzene:	**0.57 µg/m³** *
Toluene:	**1.8 µg/m³** *
Sulfur Hexafluoride:	**11 µg/m³** *
1,1-Dichloroethene:	**< 0.039 µg/m³** *
Trichloroethene:	**0.065 µg/m³** *
Radon:	**0.069 pCi/L**

Sample ID:	Indoor-1
Sample Date:	10/4/10
Benzene:	**0.59 µg/m³**
Toluene:	**2.9 µg/m³**
Sulfur Hexafluoride:	**85 µg/m³**
1,1-Dichloroethene:	**< 0.041 µg/m³**
Trichloroethene:	**0.59 µg/m³**
Radon:	**0 pCi/L**
Sample Date:	10/7/10
Benzene:	**0.56 µg/m³**
Toluene:	**1.8 µg/m³**
Sulfur Hexafluoride:	**82 µg/m³**
1,1-Dichloroethene:	**< 0.041 µg/m³**
Trichloroethene:	**0.11 µg/m³**
Radon:	**0.017 pCi/L**

Sample ID:	SS-3	Indoor-3
Sample Date:	10/4/10	10/4/10
Benzene:	**0.34 µg/m³**	**0.47 µg/m³**
Toluene:	**1.3 µg/m³**	**2.1 µg/m³**
Sulfur Hexafluoride:	**1800 µg/m³**	**2900 µg/m³**
1,1-Dichloroethene:	**1.2 µg/m³**	**0.044 µg/m³**
Trichloroethene:	**4.1 µg/m³**	**0.21 µg/m³**
Radon:	**4.5 pCi/L**	**0 pCi/L**
Sample Date:	10/7/10	10/7/10
Benzene:	**0.58 µg/m³**	**0.59 µg/m³**
Toluene:	**3.7 µg/m³**	**2.7 µg/m³**
Sulfur Hexafluoride:	**1600 µg/m³**	**1700 µg/m³**
1,1-Dichloroethene:	**2.2 µg/m³**	**< 0.039 µg/m³**
Trichloroethene:	**7.2 µg/m³**	**0.18 µg/m³**
Radon:	**2.4 pCi/L**	**0.1 pCi/L**

Sample ID:	SS-1
Sample Date:	10/4/10
Benzene:	**0.19 µg/m³**
Toluene:	**0.76 µg/m³**
Sulfur Hexafluoride:	**380 µg/m³**
1,1-Dichloroethene:	**18 µg/m³**
Trichloroethene:	**12 µg/m³**
Radon:	**600 pCi/L**
Sample Date:	10/7/10
Benzene:	**< 0.39 µg/m³**
Toluene:	**< 1.9 µg/m³**
Sulfur Hexafluoride:	**370 µg/m³**
1,1-Dichloroethene:	**20 µg/m³**
Trichloroethene:	**13 µg/m³**
Radon:	**470 pCi/L**

Sample ID:	SS-2	Indoor-2
Sample Date:	10/4/10	10/4/10
Benzene:	**0.1 µg/m³**	**0.6 µg/m³**
Toluene:	**0.38 µg/m³**	**2.4 µg/m³**
Sulfur Hexafluoride:	**1500 µg/m³**	**1800 µg/m³**
1,1-Dichloroethene:	**0.35 µg/m³**	**< 0.047 µg/m³**
Trichloroethene:	**4.6 µg/m³**	**0.2 µg/m³**
Radon:	**29 pCi/L**	**0.1 pCi/L**
Sample Date:	10/7/10	10/7/10
Benzene:	**< 0.39 µg/m³**	**0.57 µg/m³**
Toluene:	**< 2 µg/m³**	**2.3 µg/m³**
Sulfur Hexafluoride:	**1000 µg/m³**	**820 µg/m³**
1,1-Dichloroethene:	**0.43 µg/m³**	**< 0.047 µg/m³**
Trichloroethene:	**8.6 µg/m³**	**0.15 µg/m³**
Radon:	**32 pCi/L**	**0.15 pCi/L**

LEGEND

- Sub-slab sampling point
- Pressure measurement point
- Both sub-slab and pressure measurement point
- Ambient air sampling location
- Indoor air sampling location
- One or more COCs detected above the reporting limit.
- COCs not detected
- * Duplicate samples taken; average value shown

Notes:

1) COC = Constituent of Concern. COCs include volatile organic compounds.
2) SF_6 and radon were used as tracer gases.
3) VOC and SF_6 analysis by Columbia Analytical Services, Inc. in Simi Valley, California. Radon analysis by USC except for Round 1 sub-slab measurements which were collected with RAD7 portable radon detector.
4) Indoor air samples were collected adjacent to the sub-slab location, except for Indoor-1.
5) Sub-slab samples, SS-1, SS-2, and SS-3 were collected 8 inches below the slab.
6) Results rounded to 2 significant figures.

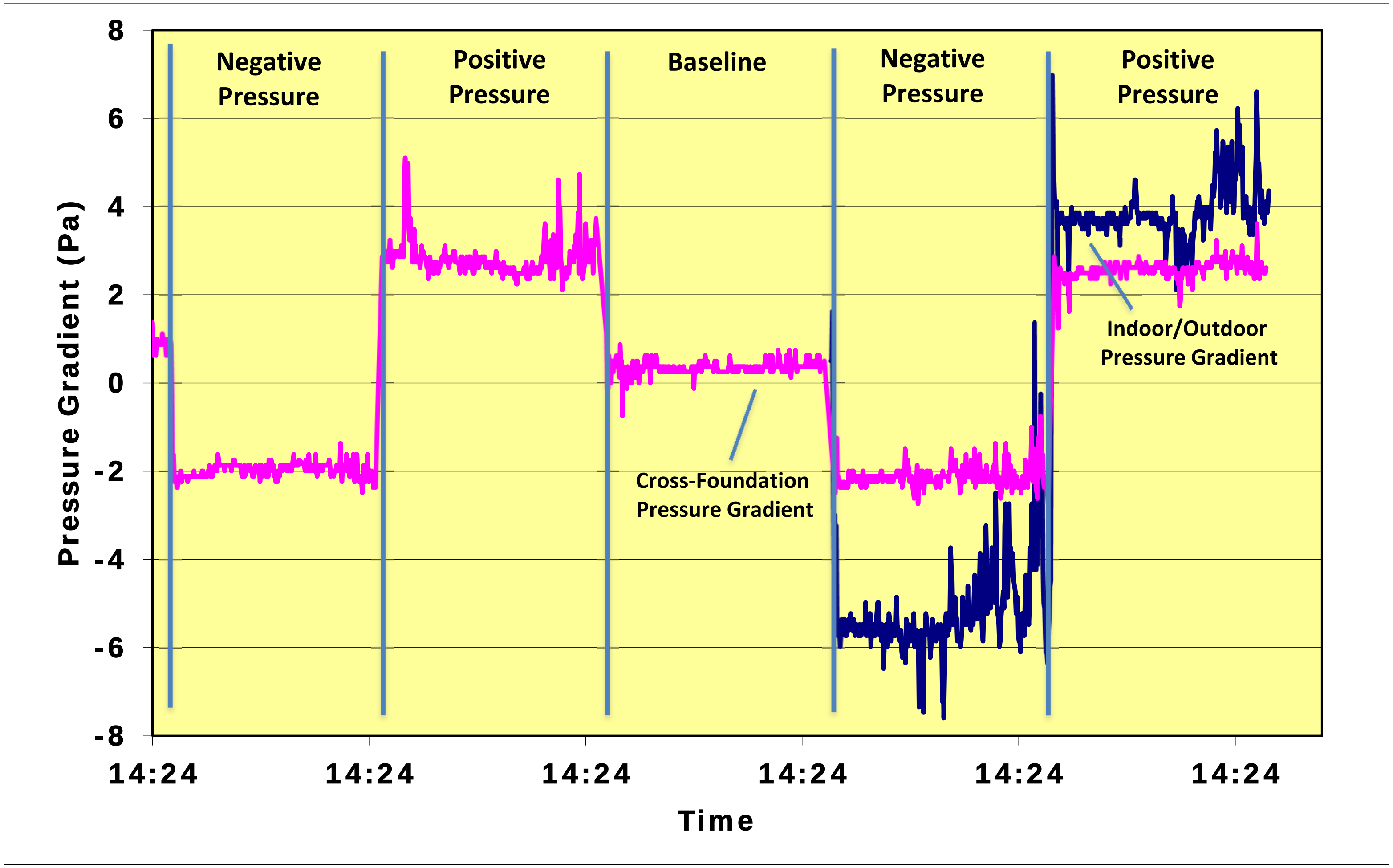
GSI ENVIRONMENTAL

SUB-SLAB AND INDOOR AIR SAMPLING AND TESTING RESULTS: POSITIVE PRESSURE

ESTCP Tier 2 Vapor Screening Study
ASU Research House, Layton, Utah

GSI Job No: G-3213		Drawn By: DLB	
Issued: 18-Nov-11		Chk'd By: LMB	
Revised: ———		Appv'd By: LMB	
Scale: As Shown		**FIGURE A.6.9**	

FIGURE A.6.10
BUILDING PRESSURE GRADIENTS
ESTCP Tier 2 Vapor Screening Study
ASU Research House, Layton, Utah



Environmental Security Technology Certification Program
(ESTCP)

FINAL REPORT

Proposed Tier 2 Screening Criteria and Tier 3 Field Procedures for Evaluation of Vapor Intrusion
ESTCP Project ER-200707

Appendix A.7: Moffett Field Naval Air Station, Moffett Field, California

TABLES

FIGURES

TABLE A.7.1
SAMPLING POINT COMPLETION DETAILS: SUB-SLAB AND PRESSURE MEASUREMENT
ESTCP Tier 2 Vapor Screening Study
Moffett Field NAS Building 107, Santa Clara County, CA

Location ID	Installed Total Depth (ft, bgs)	Boring Hole Diameter (inches)	Sand Backfill Filter Pack		Tubing Diameter (inches)
			U.S. Mesh Interval	Filter Pack Thickness (in)	
Sub-Slab Sampling Points					
SS-1	0.67	1	20/40	1	1/4
SS-2	0.67	1	20/40	1	1/4
SS-3	0.67	1	20/40	1	1/4
Pressure Measurement Points					
SS-1-P [4]	0.67	1	20/40	1	1/4
SS-2-P	0.67	1	20/40	1	1/4
SS-3-P [4]	0.67	1	20/40	1	1/4

Notes:
1. Locations are shown on Figure A.7.1.
2. All locations were completed to the surface with a bentonite seal topped with modeling clay.
3. bgs = Below ground surface.
4. Pressure measurement from the same point as sub-slab sample.

TABLE A.7.2
RESULTS OF SUB-SLAB ANALYSES: COMPOUNDS OF INTEREST
ESTCP Tier 2 Vapor Screening Study
Moffett Field NAS Building 107, Santa Clara County, CA

LOCATION ID:	Subslab-1	Subslab-1	Subslab-1	Subslab-1	Subslab-1	Subslab-1
PRESSURE CONDIT	Baseline	Negative	Positive	Baseline	Negative	Positive
SAMPLE DATE:	10/29/2010	10/30/2010	10/31/2010	11/1/2010	11/2/2010	11/3/2010
COMPOUND	µg/m^3	µg/m^3	µg/m^3	µg/m^3	µg/m^3	µg/m^3
Volatile Organic Compounds (VOCs) by Method TO-15						
Benzene	-	<3.7	**0.62**	**0.98**	**0.75**	**0.75**
Tetrachloroethene	-	<3.7	**1.2**	**2.2**	**1.4**	**0.69**
Toluene	-	<19	**3.3**	<3.7	**3.3**	**3.5**
Trichloroethene	-	<3.7	**0.9**	**3**	**1.9**	**0.73**
Radon by EPA Method GS						
Radon, pCi/L	-	-	-	**187.06**	**212.84**	**364.67**
Radon by RAD7 on-site instrument						
Radon, pCi/L	**427.65**	**260.6**	**127.76**	**164.4**	**189.96**	**98.62**
Sulfur Hexafluoride (SF6) by NIOSH 6602 Modified						
Sulfur Hexafluoride	<8.2	**97**	**330**	**1800**	**200**	**570**

Notes:
1. VOC and SF6 samples were analyzed by Columbia Analytical Services, Inc. in Simi Valley, California. Radon laboratory analysis conducted by USC.
2. Detected analytes are presented in **bold** type.
3. < = not detected at detection limit shown; "-" = not analyzed.
4. TO-15 analysis could not be conducted on Subslab-1 Baseline sample collected 10/29/2010 because of a Summa canister valve malfunction.
5. TO-15 analysis could not be conducted on Subslab-2 Positive Pressure condition sample collected 10/31/2010 due to debris in the threads of the canister valve.
6. The RAD7 instrument was programmed to report 5 measurements, with a cycle time of 5 minutes. The final concentration was calculated as the average of the last three measurements (i.e., Cycles 3, 4 and 5)
7. Compounds shown are those included in Tier 3 pressure control evaluation.

Continued on next page

GSI ENVIRONMENTAL

TABLE A.7.2 (CONTINUED)

RESULTS OF SUB-SLAB ANALYSES: COMPOUNDS OF INTEREST

ESTCP Tier 2 Vapor Screening Study

Moffett Field NAS Building 107, Santa Clara County, CA

			DUPLICATE				*DUPLICATE*	
LOCATION ID:	Subslab-2	Subslab-2	Subslab-2	Subslab-2	Subslab-2	Subslab-2	Subslab-2	Subslab-2
PRESSURE CONDITION:	Baseline	Negative	Negative	Positive	Baseline	Negative	Negative	Positive
SAMPLE DATE:	10/29/2010	10/30/2010	10/30/2010	10/31/2010	11/1/2010	11/2/2010	11/2/2010	11/3/2010
COMPOUND	µg/m^3	µg/m^3	µg/m^3	µg/m^3	µg/m^3	µg/m^3	µg/m^3	µg/m^3
Volatile Organic Compounds (VOCs) by Method TO-15								
Benzene	**0.92**	**0.87**	<0.45	-	**0.42**	**0.45**	**0.43**	**0.83**
Tetrachloroethene	**2.8**	**0.85**	**0.63**	-	**0.77**	**0.55**	**3.2**	**1**
Toluene	**6**	<2.5	<2.3	-	<1.8	<2.1	<2	**4**
Trichloroethene	<0.39	**0.5**	**0.59**	-	**0.83**	**1**	**1.3**	<0.41
Radon by EPA Method GS								
Radon, pCi/L	-	-	-	-	**89.7**	**270.62**	**281.2**	**10.71**
Radon by RAD7 on-site instrument								
Radon, pCi/L	**185.19**	**118.52**	-	**16.8**	**81.88**	**257.97**	**249.92**	**18.38**
Sulfur Hexafluoride (SF6) by NIOSH 6602 Modified								
Sulfur Hexafluoride	**95**	**24**	**22**	**350**	**1700**	**86**	**80**	**750**

Notes:

1. VOC and SF6 samples were analyzed by Columbia Analytical Services, Inc. in Simi Valley, California. Radon laboratory analysis conducted by USC.
2. Detected analytes are presented in **bold** type.
3. < = not detected at detection limit shown; "-" = not analyzed.
4. TO-15 analysis could not be conducted on Subslab-1 Baseline sample collected 10/29/2010 because of a Summa canister valve malfunction.
5. TO-15 analysis could not be conducted on Subslab-2 Positive Pressure condition sample collected 10/31/2010 due to debris in the threads of the canister valve.
6. The RAD7 instrument was programmed to report 5 measurements, with a cycle time of 5 minutes. The final concentration was calculated as the average of the last three measurements (i.e., Cycles 3, 4 and 5)
7. Compounds shown are those included in Tier 3 pressure control evaluation.

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GSI ENVIRONMENTAL

TABLE A.7.2 (CONTINUED)
RESULTS OF SUB-SLAB ANALYSES: COMPOUNDS OF INTEREST
ESTCP Tier 2 Vapor Screening Study
Moffett Field NAS Building 107, Santa Clara County, CA

LOCATION ID:	Subslab-3	Subslab-3	Subslab-3	Subslab-3	Subslab-3	Subslab-3
PRESSURE CONDITION:	Baseline	Negative	Positive	Baseline	Negative	Positive
SAMPLE DATE:	10/29/2010	10/30/2010	10/31/2010	11/1/2010	11/2/2010	11/3/2010
COMPOUND	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$
Volatile Organic Compounds (VOCs) by Method TO-15						
Benzene	**24**	**8.3**	**4.4**	**2.7**	**2**	**1.5**
Tetrachloroethene	**3.5**	**3**	**3.1**	**3.1**	**6.2**	**3.2**
Toluene	**40**	**20**	**13**	**7.1**	**5.8**	**4.8**
Trichloroethene	**2.3**	**2.2**	**2.2**	**2.2**	**2.5**	**2.3**
Radon by EPA Method GS						
Radon, pCi/L	-	-	-	**613.88**	**632.47**	**695.12**
Radon by RAD7 on-site instrument						
Radon, pCi/L	**603.72**	**621.08**	**604.25**	**554.95**	**641.32**	**618.78**
Sulfur Hexafluoride (SF6) by NIOSH 6602 Modified						
Sulfur Hexafluoride	**16**	**39**	**23**	**100**	**72**	**90**

Notes:
1. VOC and SF6 samples were analyzed by Columbia Analytical Services, Inc. in Simi Valley, California. Radon laboratory analysis conducted by USC.
2. Detected analytes are presented in **bold** type.
3. < = not detected at detection limit shown; "-" = not analyzed.
4. TO-15 analysis could not be conducted on Subslab-1 Baseline sample collected 10/29/2010 because of a Summa canister valve malfunction.
5. TO-15 analysis could not be conducted on Subslab-2 Positive Pressure condition sample collected 10/31/2010 due to debris in the threads of the canister valve.
6. The RAD7 instrument was programmed to report 5 measurements, with a cycle time of 5 minutes. The final concentration was calculated as the average of the last three measurements (i.e., Cycles 3, 4 and 5)
7. Compounds shown are those included in Tier 3 pressure control evaluation.

TABLE A.7.3
RESULTS OF INDOOR AND AMBIENT AIR ANALYSES: COMPOUNDS OF INTEREST
ESTCP Tier 2 Vapor Screening Study
Moffett Field NAS Building 107, Santa Clara County, CA

LOCATION ID:	Indoor-1	Indoor-1	Indoor-1	Indoor-1	Indoor-1	Indoor-1
PRESSURE CONDIT	Baseline	Negative	Positive	Baseline	Negative	Positive
SAMPLE DATE:	10/29/2010	10/30/2010	10/31/2010	11/1/2010	11/2/2010	11/3/2010
COMPOUND	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$
Volatile Organic Compounds (VOCs) by Method TO-15 SIM						
Benzene	**0.46**	**0.27**	**0.4**	**1.1**	**1.5**	**1.5**
Tetrachloroethene	**1.8**	**1.3**	**0.095**	**2.7**	**1.5**	**0.44**
Toluene	**2.1**	**1.7**	**3.1**	**3.7**	**5.4**	**8.6**
Trichloroethene	**2.8**	**2**	**0.077**	**4.7**	**2.3**	**0.12**
Radon by EPA Method GS						
Radon, pCi/L	**0.59**	**0.24**	0	**1.01**	**0.52**	**0.35**
Sulfur Hexafluoride (SF6) by NIOSH 6602 Modified						
Sulfur Hexafluoride	**1400**	**140**	**420**	**3000**	**310**	**790**

Notes:
1. VOC and SF6 samples were analyzed by Columbia Analytical Services, Inc. in Simi Valley, California. Radon laboratory analysis conducted by USC.
2. Detected analytes are presented in **bold** type.
3. < = not detected at detection limit shown; "-" = not analyzed.
4. Compounds shown are those included in Tier 3 pressure control evaluation.

Continued on next page

TABLE A.7.3 (CONTINUED)

RESULTS OF INDOOR AND AMBIENT AIR ANALYSES: COMPOUNDS OF INTEREST

ESTCP Tier 2 Vapor Screening Study

Moffett Field NAS Building 107, Santa Clara County, CA

					DUPLICATE		
LOCATION ID:	Indoor-2	Indoor-2	Indoor-2	Indoor-2	Indoor-2	Indoor-2	Indoor-2
PRESSURE CONDITION:	Baseline	Negative	Positive	Baseline	Baseline	Negative	Positive
SAMPLE DATE:	10/29/2010	10/30/2010	10/31/2010	11/1/2010	11/1/2010	11/2/2010	11/3/2010
COMPOUND	μg/m^3	μg/m^3	μg/m^3	μg/m^3	μg/m^3	μg/m^3	μg/m^3
Volatile Organic Compounds (VOCs) by Method TO-15 SIM							
Benzene	**0.45**	**0.24**	**0.36**	**1.1**	**1.2**	**1.7**	**1.6**
Tetrachloroethene	**1.7**	**1.5**	**0.066**	**2.9**	**2.9**	**1.9**	**0.41**
Toluene	**1.5**	**0.87**	**1.3**	**4**	**4.6**	**8.3**	**8.4**
Trichloroethene	**2.7**	**2.2**	**0.056**	**5**	**5.1**	**3**	**0.1**
Radon by EPA Method GS							
Radon, pCi/L	**0.71**	**0.54**	0	**0.92**	**1.18**	**0.53**	**0.37**
Sulfur Hexafluoride (SF6) by NIOSH 6602 Modified							
Sulfur Hexafluoride	**1600**	**250**	**410**	**3400**	**3200**	**600**	**790**

Notes:

1. VOC and SF6 samples were analyzed by Columbia Analytical Services, Inc. in Simi Valley, California. Radon laboratory analysis conducted by USC.
2. Detected analytes are presented in **bold** type.
3. < = not detected at detection limit shown; "-" = not analyzed.
4. Compounds shown are those included in Tier 3 pressure control evaluation.

Continued on next page

GSI ENVIRONMENTAL

TABLE A.7.3 (CONTINUED)

RESULTS OF INDOOR AND AMBIENT AIR ANALYSES: COMPOUNDS OF INTEREST
ESTCP Tier 2 Vapor Screening Study
Moffett Field NAS Building 107, Santa Clara County, CA

LOCATION ID:	Indoor-3	Indoor-3	Indoor-3	Indoor-3	Indoor-3	Indoor-3
PRESSURE CONDITION:	Baseline	Negative	Positive	Baseline	Negative	Positive
SAMPLE DATE:	10/29/2010	10/30/2010	10/31/2010	11/1/2010	11/2/2010	11/3/2010
COMPOUND	µg/m^3	µg/m^3	µg/m^3	µg/m^3	µg/m^3	µg/m^3
Volatile Organic Compounds (VOCs) by Method TO-15 SIM						
Benzene	**0.45**	**0.27**	**0.7**	**1.1**	**1.5**	**1.5**
Tetrachloroethene	**2.2**	**1.9**	**0.13**	**2.9**	**2.6**	**0.41**
Toluene	**1.9**	**1.3**	**11**	**4**	**15**	**8.5**
Trichloroethene	**3.3**	**2.8**	**0.13**	**5.1**	**4.1**	**0.13**
Radon by EPA Method GS						
Radon, pCi/L	-	**0.6**	**0.19**	**0.95**	**0.8**	**0.19**
Sulfur Hexafluoride (SF6) by NIOSH 6602 Modified						
Sulfur Hexafluoride	**1800**	**380**	**330**	**3500**	**780**	<10

Notes:

1. VOC and SF6 samples were analyzed by Columbia Analytical Services, Inc. in Simi Valley, California. Radon laboratory analysis conducted by USC.
2. Detected analytes are presented in **bold** type.
3. < = not detected at detection limit shown; "-" = not analyzed.
4. Compounds shown are those included in Tier 3 pressure control evaluation.

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TABLE A.7.3 (CONTINUED)

RESULTS OF INDOOR AND AMBIENT AIR ANALYSES: COMPOUNDS OF INTEREST

ESTCP Tier 2 Vapor Screening Study

Moffett Field NAS Building 107, Santa Clara County, CA

				DUPLICATE			
LOCATION ID:	Ambient-1	Ambient-1	Ambient-1	Ambient-1	Ambient-1	Ambient-1	Ambient-1
PRESSURE CONDITION:	Baseline	Negative	Positive	Positive	Baseline	Negative	Positive
SAMPLE DATE:	10/29/2010	10/30/2010	10/31/2010	10/31/2010	11/1/2010	11/2/2010	11/3/2010
COMPOUND	μg/m^3	μg/m^3	μg/m^3	μg/m^3	μg/m^3	μg/m^3	μg/m^3
Volatile Organic Compounds (VOCs) by Method TO-15 SIM							
Benzene	**0.46**	**0.27**	**0.3**	**0.5**	**1.1**	**1.5**	**1.4**
Tetrachloroethene	**0.082**	**0.052**	**0.047**	**0.074**	**0.12**	**0.21**	**0.89**
Toluene	**2.1**	**3.4**	**1.1**	**2.1**	**3.5**	**9.4**	**10**
Trichloroethene	**0.045**	<0.038	<0.041	**0.056**	**0.084**	**0.12**	**0.089**
Radon by EPA Method GS							
Radon, pCi/L	**0.12**	**0.03**	**0.03**	**0.07**	**0.18**	**0.26**	**0.33**
Sulfur Hexafluoride (SF6) by NIOSH 6602 Modified							
Sulfur Hexafluoride	<9.1	<9.1	<9.7	<12	**18**	**16**	**18**

Notes:

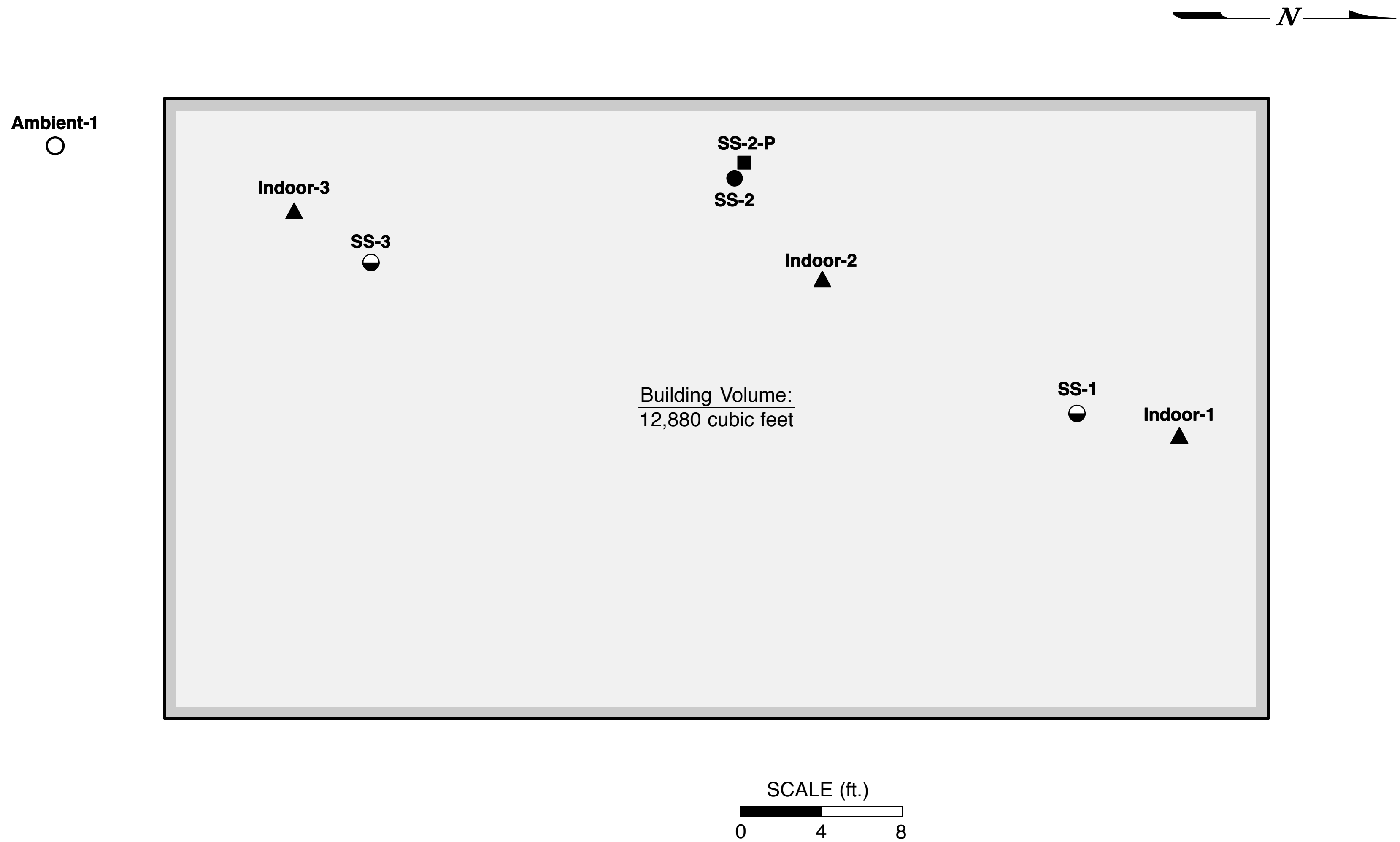
1. VOC and SF6 samples were analyzed by Columbia Analytical Services, Inc. in Simi Valley, California. Radon laboratory analysis conducted by USC.
2. Detected analytes are presented in **bold** type.
3. < = not detected at detection limit shown; "-" = not analyzed.
4. Compounds shown are those included in Tier 3 pressure control evaluation.

GSI ENVIRONMENTAL

TABLE A.7.4
PRESSURE GRADIENT MEASUREMENTS FROM ADDITIONAL LOCATIONS
ESTCP Tier 2 Vapor Screening Study
Moffett Field NAS Building 107, Santa Clara County, CA

Condition	Pressure Gradient (Pa)		
	Time	SS-1	SS-3
Round 1			
Depressurization with fan on high (Speed 3)	10/30/11 17:30	0.000 to -0.747	-1.245 to -2.739
Pressurization with fan on high (Speed 3)	10/31/10 15:30	0.000 to +1.245	+0.747 to +4.731
Round 2			
Baseline (fan turned off)	11/1/10 15:30	0.000 to +0.498	-0.498 to -1.743
Depressurization with fan on high (Speed 3)	11/2/10 15:30	-0.498	-0.747 to -1.743
Pressurization with fan on high (Speed 3)	11/3/2010	NR	NR

Notes:
1. Hand recorded readings from pressure transducer.
2. NR = not recorded



LEGEND

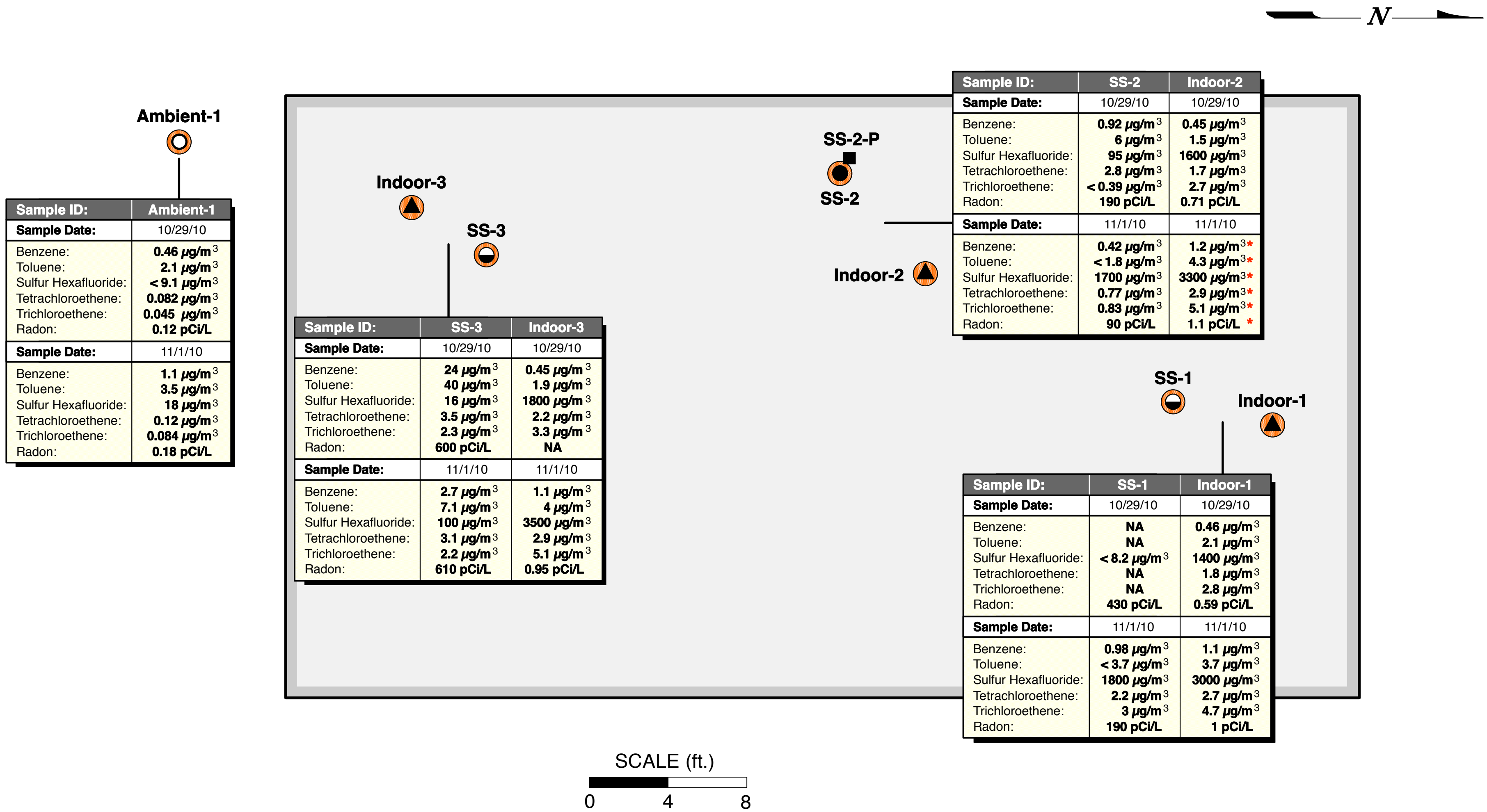
- ● Sub-slab sampling point
- ◒ Both sub-slab and pressure measurement point
- ■ Pressure measurement point
- ○ Ambient air sampling location
- ▲ Indoor air sampling location

GSI ENVIRONMENTAL

SUB-SLAB, INDOOR AND AMBIENT AIR SAMPLING AND MEASUREMENT LOCATIONS

ESTCP Tier 2 Vapor Screening Study
Building 107, Moffett Field NAS, California

GSI Job No:	G-3213	Drawn By:	DLB
Issued:	18-Nov-11	Chk'd By:	DMB
Revised:	———	Appv'd By:	LMB
Scale:	As Shown		**FIGURE A.7.1**



Sample ID:	Ambient-1
Sample Date:	10/29/10
Benzene:	0.46 $\mu g/m^3$
Toluene:	2.1 $\mu g/m^3$
Sulfur Hexafluoride:	< 9.1 $\mu g/m^3$
Tetrachloroethene:	0.082 $\mu g/m^3$
Trichloroethene:	0.045 $\mu g/m^3$
Radon:	0.12 pCi/L
Sample Date:	11/1/10
Benzene:	1.1 $\mu g/m^3$
Toluene:	3.5 $\mu g/m^3$
Sulfur Hexafluoride:	18 $\mu g/m^3$
Tetrachloroethene:	0.12 $\mu g/m^3$
Trichloroethene:	0.084 $\mu g/m^3$
Radon:	0.18 pCi/L

Sample ID:	SS-3	Indoor-3
Sample Date:	10/29/10	10/29/10
Benzene:	24 $\mu g/m^3$	0.45 $\mu g/m^3$
Toluene:	40 $\mu g/m^3$	1.9 $\mu g/m^3$
Sulfur Hexafluoride:	16 $\mu g/m^3$	1800 $\mu g/m^3$
Tetrachloroethene:	3.5 $\mu g/m^3$	2.2 $\mu g/m^3$
Trichloroethene:	2.3 $\mu g/m^3$	3.3 $\mu g/m^3$
Radon:	600 pCi/L	NA
Sample Date:	11/1/10	11/1/10
Benzene:	2.7 $\mu g/m^3$	1.1 $\mu g/m^3$
Toluene:	7.1 $\mu g/m^3$	4 $\mu g/m^3$
Sulfur Hexafluoride:	100 $\mu g/m^3$	3500 $\mu g/m^3$
Tetrachloroethene:	3.1 $\mu g/m^3$	2.9 $\mu g/m^3$
Trichloroethene:	2.2 $\mu g/m^3$	5.1 $\mu g/m^3$
Radon:	610 pCi/L	0.95 pCi/L

Sample ID:	SS-2	Indoor-2
Sample Date:	10/29/10	10/29/10
Benzene:	0.92 $\mu g/m^3$	0.45 $\mu g/m^3$
Toluene:	6 $\mu g/m^3$	1.5 $\mu g/m^3$
Sulfur Hexafluoride:	95 $\mu g/m^3$	1600 $\mu g/m^3$
Tetrachloroethene:	2.8 $\mu g/m^3$	1.7 $\mu g/m^3$
Trichloroethene:	< 0.39 $\mu g/m^3$	2.7 $\mu g/m^3$
Radon:	190 pCi/L	0.71 pCi/L
Sample Date:	11/1/10	11/1/10
Benzene:	0.42 $\mu g/m^3$	1.2 $\mu g/m^3$*
Toluene:	< 1.8 $\mu g/m^3$	4.3 $\mu g/m^3$*
Sulfur Hexafluoride:	1700 $\mu g/m^3$	3300 $\mu g/m^3$*
Tetrachloroethene:	0.77 $\mu g/m^3$	2.9 $\mu g/m^3$*
Trichloroethene:	0.83 $\mu g/m^3$	5.1 $\mu g/m^3$*
Radon:	90 pCi/L	1.1 pCi/L *

Sample ID:	SS-1	Indoor-1
Sample Date:	10/29/10	10/29/10
Benzene:	NA	0.46 $\mu g/m^3$
Toluene:	NA	2.1 $\mu g/m^3$
Sulfur Hexafluoride:	< 8.2 $\mu g/m^3$	1400 $\mu g/m^3$
Tetrachloroethene:	NA	1.8 $\mu g/m^3$
Trichloroethene:	NA	2.8 $\mu g/m^3$
Radon:	430 pCi/L	0.59 pCi/L
Sample Date:	11/1/10	11/1/10
Benzene:	0.98 $\mu g/m^3$	1.1 $\mu g/m^3$
Toluene:	< 3.7 $\mu g/m^3$	3.7 $\mu g/m^3$
Sulfur Hexafluoride:	1800 $\mu g/m^3$	3000 $\mu g/m^3$
Tetrachloroethene:	2.2 $\mu g/m^3$	2.7 $\mu g/m^3$
Trichloroethene:	3 $\mu g/m^3$	4.7 $\mu g/m^3$
Radon:	190 pCi/L	1 pCi/L

LEGEND

- ● Sub-slab sampling point
- ■ Pressure measurement point
- ◓ Both sub-slab and pressure measurement point
- ○ Ambient air sampling location
- ▲ Indoor air sampling location
- One or more COCs detected above the reporting limit.
- COCs not detected
- * Duplicate samples taken; average value shown

Notes:

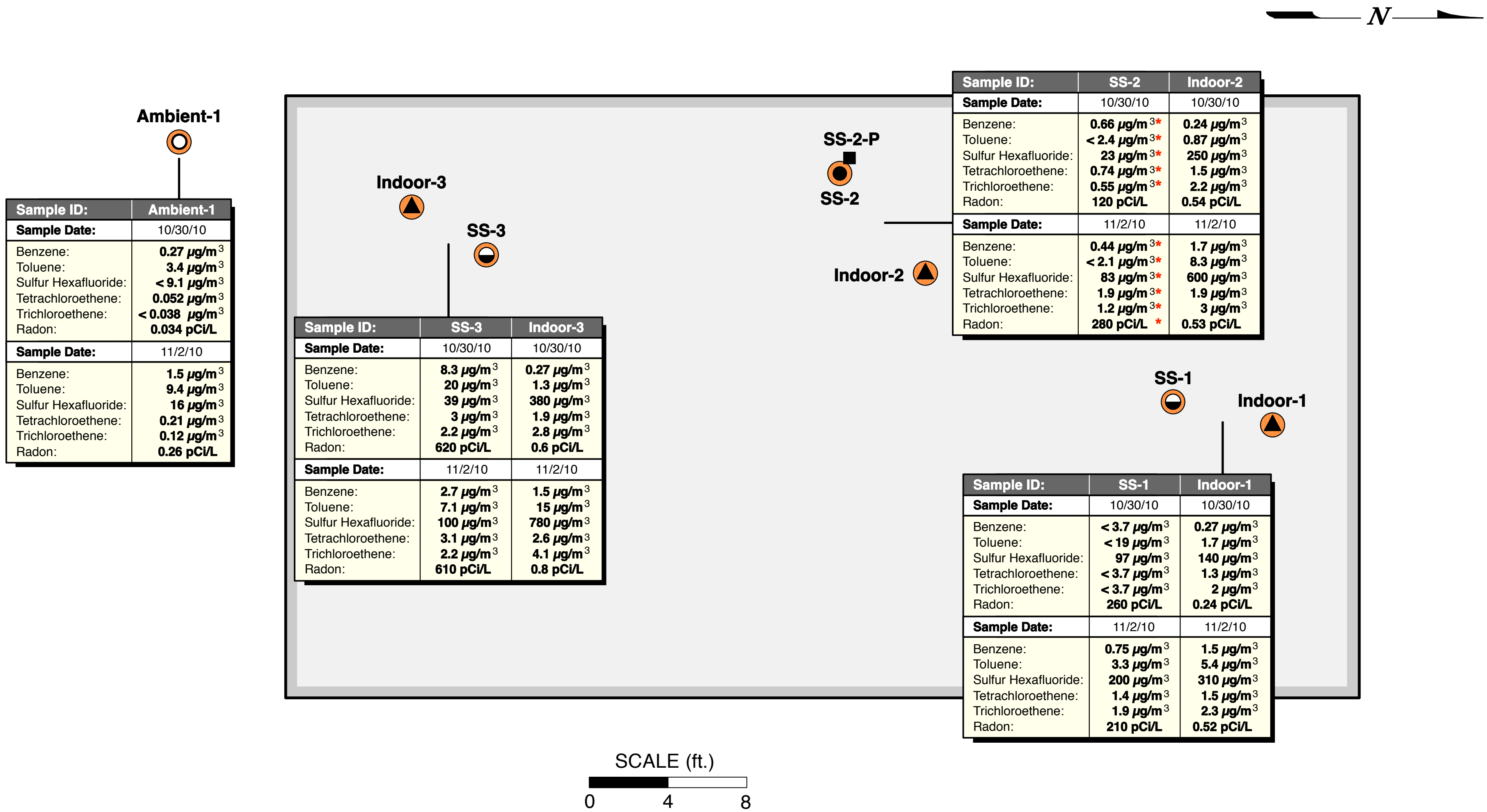
1) COC = Constituent of Concern. COCs include volatile organic compounds.
2) SF_6 and radon were used as tracer gases.
3) VOC and SF_6 analysis by Columbia Analytical Services, Inc. in Simi Valley, California. Radon analysis by USC except for Round 1 sub-slab measurements which were collected with RAD7 portable radon detector.
4) Indoor air samples were collected adjacent to the sub-slab location, except for Indoor-1.
5) Sub-slab samples, SS-1, SS-2, and SS-3 were collected 8 inches below the slab.
6) Results rounded to 2 significant figures.
7) NA = Not analyzed.

GSI ENVIRONMENTAL

SUB-SLAB AND INDOOR AIR SAMPLING AND TESTING RESULTS: BASELINE

ESTCP Tier 2 Vapor Screening Study
Building 107, Moffett Field NAS, California

GSI Job No:	G-3213	Drawn By:	DLB
Issued:	18-Nov-11	Chk'd By:	LMB
Revised:	————	Appv'd By:	LMB
Scale:	As Shown		**FIGURE A.7.2**



Sample ID:	Ambient-1
Sample Date:	10/30/10
Benzene:	0.27 μg/m^3
Toluene:	3.4 μg/m^3
Sulfur Hexafluoride:	< 9.1 μg/m^3
Tetrachloroethene:	0.052 μg/m^3
Trichloroethene:	< 0.038 μg/m^3
Radon:	0.034 pCi/L
Sample Date:	11/2/10
Benzene:	1.5 μg/m^3
Toluene:	9.4 μg/m^3
Sulfur Hexafluoride:	16 μg/m^3
Tetrachloroethene:	0.21 μg/m^3
Trichloroethene:	0.12 μg/m^3
Radon:	0.26 pCi/L

Sample ID:	SS-3	Indoor-3
Sample Date:	10/30/10	10/30/10
Benzene:	8.3 μg/m^3	0.27 μg/m^3
Toluene:	20 μg/m^3	1.3 μg/m^3
Sulfur Hexafluoride:	39 μg/m^3	380 μg/m^3
Tetrachloroethene:	3 μg/m^3	1.9 μg/m^3
Trichloroethene:	2.2 μg/m^3	2.8 μg/m^3
Radon:	620 pCi/L	0.6 pCi/L
Sample Date:	11/2/10	11/2/10
Benzene:	2.7 μg/m^3	1.5 μg/m^3
Toluene:	7.1 μg/m^3	15 μg/m^3
Sulfur Hexafluoride:	100 μg/m^3	780 μg/m^3
Tetrachloroethene:	3.1 μg/m^3	2.6 μg/m^3
Trichloroethene:	2.2 μg/m^3	4.1 μg/m^3
Radon:	610 pCi/L	0.8 pCi/L

Sample ID:	SS-2	Indoor-2
Sample Date:	10/30/10	10/30/10
Benzene:	0.66 μg/m^3 *	0.24 μg/m^3
Toluene:	< 2.4 μg/m^3 *	0.87 μg/m^3
Sulfur Hexafluoride:	23 μg/m^3 *	250 μg/m^3
Tetrachloroethene:	0.74 μg/m^3 *	1.5 μg/m^3
Trichloroethene:	0.55 μg/m^3 *	2.2 μg/m^3
Radon:	120 pCi/L	0.54 pCi/L
Sample Date:	11/2/10	11/2/10
Benzene:	0.44 μg/m^3 *	1.7 μg/m^3
Toluene:	< 2.1 μg/m^3 *	8.3 μg/m^3
Sulfur Hexafluoride:	83 μg/m^3 *	600 μg/m^3
Tetrachloroethene:	1.9 μg/m^3 *	1.9 μg/m^3
Trichloroethene:	1.2 μg/m^3 *	3 μg/m^3
Radon:	280 pCi/L *	0.53 pCi/L

Sample ID:	SS-1	Indoor-1
Sample Date:	10/30/10	10/30/10
Benzene:	< 3.7 μg/m^3	0.27 μg/m^3
Toluene:	< 19 μg/m^3	1.7 μg/m^3
Sulfur Hexafluoride:	97 μg/m^3	140 μg/m^3
Tetrachloroethene:	< 3.7 μg/m^3	1.3 μg/m^3
Trichloroethene:	< 3.7 μg/m^3	2 μg/m^3
Radon:	260 pCi/L	0.24 pCi/L
Sample Date:	11/2/10	11/2/10
Benzene:	0.75 μg/m^3	1.5 μg/m^3
Toluene:	3.3 μg/m^3	5.4 μg/m^3
Sulfur Hexafluoride:	200 μg/m^3	310 μg/m^3
Tetrachloroethene:	1.4 μg/m^3	1.5 μg/m^3
Trichloroethene:	1.9 μg/m^3	2.3 μg/m^3
Radon:	210 pCi/L	0.52 pCi/L

LEGEND

- Sub-slab sampling point
- Pressure measurement point
- Both sub-slab and pressure measurement point
- Ambient air sampling location
- Indoor air sampling location
- One or more COCs detected above the reporting limit.
- COCs not detected
- * Duplicate samples taken; average value shown

Notes:

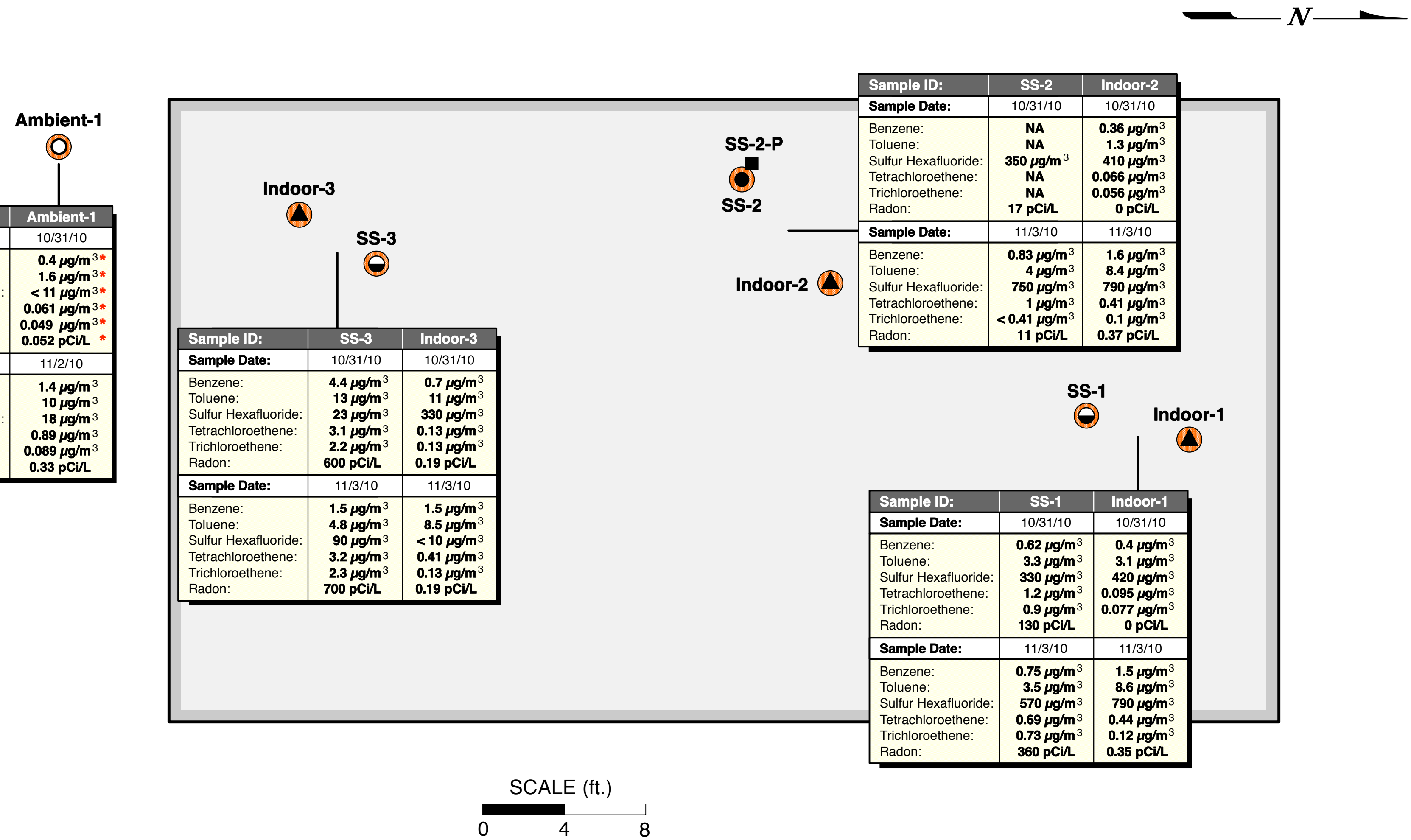
1) COC = Constituent of Concern. COCs include volatile organic compounds.
2) SF_6 and radon were used as tracer gases.
3) VOC and SF_6 analysis by Columbia Analytical Services, Inc. in Simi Valley, California. Radon analysis by USC except for Round 1 sub-slab measurements which were collected with RAD7 portable radon detector.
4) Indoor air samples were collected adjacent to the sub-slab location, except for Indoor-1.
5) Sub-slab samples, SS-1, SS-2, and SS-3 were collected 8 inches below the slab.
6) Results rounded to 2 significant figures.
7) NA = Not analyzed.

GSI ENVIRONMENTAL

SUB-SLAB AND INDOOR AIR SAMPLING AND TESTING RESULTS: NEGATIVE PRESSURE

ESTCP Tier 2 Vapor Screening Study
Building 107, Moffett Field NAS, California

GSI Job No:	G-3213	Drawn By:	DLB
Issued:	18-Nov-11	Chk'd By:	LMB
Revised:	———	Appv'd By:	LMB
Scale:	As Shown		**FIGURE A.7.3**



Sample ID:	Ambient-1
Sample Date:	10/31/10
Benzene:	**0.4 µg/m^3** *
Toluene:	**1.6 µg/m^3** *
Sulfur Hexafluoride:	**< 11 µg/m^3** *
Tetrachloroethene:	**0.061 µg/m^3** *
Trichloroethene:	**0.049 µg/m^3** *
Radon:	**0.052 pCi/L** *
Sample Date:	11/2/10
Benzene:	**1.4 µg/m^3**
Toluene:	**10 µg/m^3**
Sulfur Hexafluoride:	**18 µg/m^3**
Tetrachloroethene:	**0.89 µg/m^3**
Trichloroethene:	**0.089 µg/m^3**
Radon:	**0.33 pCi/L**

Sample ID:	SS-3	Indoor-3
Sample Date:	10/31/10	10/31/10
Benzene:	**4.4 µg/m^3**	**0.7 µg/m^3**
Toluene:	**13 µg/m^3**	**11 µg/m^3**
Sulfur Hexafluoride:	**23 µg/m^3**	**330 µg/m^3**
Tetrachloroethene:	**3.1 µg/m^3**	**0.13 µg/m^3**
Trichloroethene:	**2.2 µg/m^3**	**0.13 µg/m^3**
Radon:	**600 pCi/L**	**0.19 pCi/L**
Sample Date:	11/3/10	11/3/10
Benzene:	**1.5 µg/m^3**	**1.5 µg/m^3**
Toluene:	**4.8 µg/m^3**	**8.5 µg/m^3**
Sulfur Hexafluoride:	**90 µg/m^3**	**< 10 µg/m^3**
Tetrachloroethene:	**3.2 µg/m^3**	**0.41 µg/m^3**
Trichloroethene:	**2.3 µg/m^3**	**0.13 µg/m^3**
Radon:	**700 pCi/L**	**0.19 pCi/L**

Sample ID:	SS-2	Indoor-2
Sample Date:	10/31/10	10/31/10
Benzene:	**NA**	**0.36 µg/m^3**
Toluene:	**NA**	**1.3 µg/m^3**
Sulfur Hexafluoride:	**350 µg/m^3**	**410 µg/m^3**
Tetrachloroethene:	**NA**	**0.066 µg/m^3**
Trichloroethene:	**NA**	**0.056 µg/m^3**
Radon:	**17 pCi/L**	**0 pCi/L**
Sample Date:	11/3/10	11/3/10
Benzene:	**0.83 µg/m^3**	**1.6 µg/m^3**
Toluene:	**4 µg/m^3**	**8.4 µg/m^3**
Sulfur Hexafluoride:	**750 µg/m^3**	**790 µg/m^3**
Tetrachloroethene:	**1 µg/m^3**	**0.41 µg/m^3**
Trichloroethene:	**< 0.41 µg/m^3**	**0.1 µg/m^3**
Radon:	**11 pCi/L**	**0.37 pCi/L**

Sample ID:	SS-1	Indoor-1
Sample Date:	10/31/10	10/31/10
Benzene:	**0.62 µg/m^3**	**0.4 µg/m^3**
Toluene:	**3.3 µg/m^3**	**3.1 µg/m^3**
Sulfur Hexafluoride:	**330 µg/m^3**	**420 µg/m^3**
Tetrachloroethene:	**1.2 µg/m^3**	**0.095 µg/m^3**
Trichloroethene:	**0.9 µg/m^3**	**0.077 µg/m^3**
Radon:	**130 pCi/L**	**0 pCi/L**
Sample Date:	11/3/10	11/3/10
Benzene:	**0.75 µg/m^3**	**1.5 µg/m^3**
Toluene:	**3.5 µg/m^3**	**8.6 µg/m^3**
Sulfur Hexafluoride:	**570 µg/m^3**	**790 µg/m^3**
Tetrachloroethene:	**0.69 µg/m^3**	**0.44 µg/m^3**
Trichloroethene:	**0.73 µg/m^3**	**0.12 µg/m^3**
Radon:	**360 pCi/L**	**0.35 pCi/L**

LEGEND

- ● Sub-slab sampling point
- ■ Pressure measurement point
- ◒ Both sub-slab and pressure measurement point
- ○ Ambient air sampling location
- ▲ Indoor air sampling location
- (orange) One or more COCs detected above the reporting limit.
- (light blue) COCs not detected
- * Duplicate samples taken; average value shown

Notes:

1) COC = Constituent of Concern. COCs include volatile organic compounds.
2) SF_6 and radon were used as tracer gases.
3) VOC and SF_6 analysis by Columbia Analytical Services, Inc. in Simi Valley, California. Radon analysis by USC except for Round 1 sub-slab measurements which were collected with RAD7 portable radon detector.
4) Indoor air samples were collected adjacent to the sub-slab location, except for Indoor-1.
5) Sub-slab samples, SS-1, SS-2, and SS-3 were collected 8 inches below the slab.
6) Results rounded to 2 significant figures.
7) NA = Not analyzed.

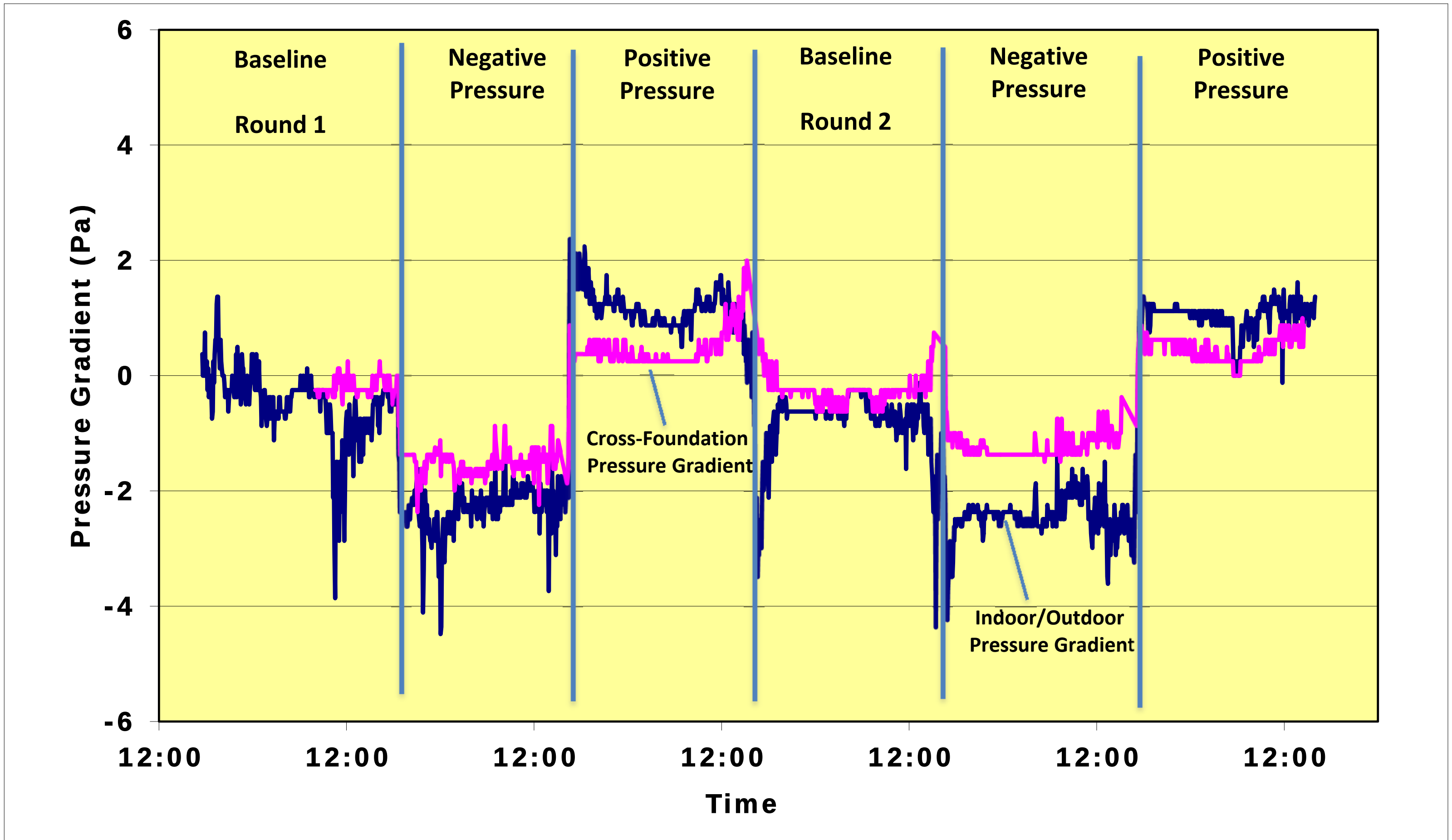
GSI ENVIRONMENTAL

SUB-SLAB AND INDOOR AIR SAMPLING AND TESTING RESULTS: POSITIVE PRESSURE

ESTCP Tier 2 Vapor Screening Study
Building 107, Moffett Field NAS, California

GSI Job No:	G-3213	Drawn By:	DLB
Issued:	18-Nov-11	Chk'd By:	LMB
Revised:	———	Appv'd By:	LMB
Scale:	As Shown		**FIGURE A.7.4**

FIGURE A.7.5
BUILDING PRESSURE GRADIENTS
ESTCP Tier 2 Vapor Screening Study
Building 107, Moffett Field NAS, California



Environmental Security Technology Certification Program
(ESTCP)

FINAL REPORT

Proposed Tier 2 Screening Criteria and Tier 3 Field Procedures for Evaluation of Vapor Intrusion
ESTCP Project ER-200707

Appendix A.8: SPAWAR OTC Facility, San Diego, California

TABLES

FIGURES

GSI ENVIRONMENTAL

TABLE A.8.1
RESULTS OF GEOTECHNICAL ANALYSES

ESTCP Tier 2 Vapor Screening Study

Buildings 3 and 28
SPAWAR OTC Facility, San Diego, California

Sample ID	Sample Depth	Dry Bulk Density	Fraction Organic Carbon	Volumetric Water Content	Porosity Total	Porosity Air Filled	Intrinsic Permeability to Water (5 PSI Confining Stress)	Native Hydraulic Conductivity (5 PSI Confining Stress)
Units	ft	pcf	%	%	--	--	cm^2	cm/sec
C1-PZ-2	1.5-2.5	82.1	1.3	25.9	0.518	0.259	NM	NM
C1-PZ-2	4.5-5.5	76.1	0.6	24.4	0.571	0.327	NM	NM
C1-PZ-2	8.5-9.5	92.6	2.0	28.5	0.462	0.177	NM	NM
C1-PZ-2	10.5-11.5	98.2	1.2	42.5	0.438	0.013	NM	NM
C1-PZ-2	12.5-13.5	93.4	0.5	33.8	0.463	0.124	NM	NM
C1-PZ-2	15-16	102.1	0.5	35.7	0.411	0.054	NM	NM
C2-PZ-1	1-2	95.1	1.1	25.1	0.430	0.178	NM	NM
C2-PZ-1	9.5-10.5	86.5	1.7	48.0	0.502	0.022	NM	NM
C2-PZ-1	12-13	95.9	0.6	39.5	0.442	0.047	NM	NM
C2-PZ-1	14-15	88.4	1.9	38.4	0.487	0.104	NM	NM
C3-PZ-2	2.5-3.5	99.0	1.2	26.2	0.410	0.149	NM	NM
C3-PZ-2	8-9.25	96.2	1.7	42.7	0.449	0.022	NM	NM
C3-PZ-2	12.5-13.5	96.4	1.0	39.5	0.451	0.056	NM	NM
C3-PZ-2	14.5-15.5	101.1	0.5	37.8	0.410	0.033	NM	NM

Notes:
1. Samples were analyzed by Fugro Consultants, Inc. in Houston, Texas.
2. Dry bulk density and volumetric moisture content determined by ASTM Method D 2166; Fraction Organic Carbon determined by ASTM Method D 2974; and total and air-filled porosity determined by ASTM Method D 854.
3. All sample orientations were vertical.
4. NM = No measurement; All samples were fractured upon delivery to the laboratory or were too non-cohesive, prohibiting the laboratory from analyzing for intrinsic permeability or native hydraulic conductivity.

GSI ENVIRONMENTAL

TABLE A.8.2
SAMPLING POINT COMPLETION DETAILS: CLUSTERS

ESTCP Tier 2 Vapor Screening Study

Buildings 3 and 28
SPAWAR OTC Facility, San Diego, California

Well ID	Installed Total Depth (ft, bgs)	Screen Interval Depth (ft, bgs)	Screen Slot Size (--)	Boring Hole Diameter (inches)	Well Diameter (inches)	Sand Backfill Filter Pack		Tubing Diameter (inches)
						U.S. Mesh Interval	Filter Pack Thickness (ft)	
Cluster 1								
Groundwater Sampling Points								
C1-PZ-1	14.0	13.5-14	No. 010	2.25	0.75	20/40	0.75	N/A
C1-PZ-2	12.25	11.75-12.25	No. 010	2.25	0.75	20/40	0.75	N/A
C1-PZ-3	11.0	10.5-11	No. 010	2.25	0.75	20/40	0.75	N/A
C1-PZ-4	10.0	9.5-10	No. 010	2.25	0.75	20/40	0.75	N/A
C1-PZ-5	9.5	9-9.5	No. 010	2.25	0.75	20/40	0.75	N/A
Soil Gas Sampling Points								
C1-SG-1	10.0	N/A	N/A	2.25	N/A	20/40	0.5	1/8
C1-SG-2	9.5	N/A	N/A	2.25	N/A	20/40	0.5	1/8
C1-SG-3	7.5	N/A	N/A	2.25	N/A	20/40	0.5	1/8
C1-SG-4	5.0	N/A	N/A	2.25	N/A	20/40	0.5	1/8
C1-SG-5	2.0	N/A	N/A	2.25	N/A	20/40	0.5	1/8
Cluster 2								
Groundwater Sampling Points								
C2-PZ-1	15.0	14.5-15	No. 010	2.25	0.75	20/40	0.75	N/A
C2-PZ-2	12.5	12-12.5	No. 010	2.25	0.75	20/40	0.75	N/A
C2-PZ-3	12.0	11.5-12	No. 010	2.25	0.75	20/40	0.75	N/A
C2-PZ-4	11.0	10.5-11	No. 010	2.25	0.75	20/40	0.75	N/A
C2-PZ-5	10.5	10-10.5	No. 010	2.25	0.75	20/40	0.75	N/A
Soil Gas Sampling Points								
C2-SG-1	11.0	N/A	N/A	2.25	N/A	20/40	0.5	1/8
C2-SG-2	10.5	N/A	N/A	2.25	N/A	20/40	0.5	1/8
C2-SG-3	7.5	N/A	N/A	2.25	N/A	20/40	0.5	1/8
C2-SG-4	4.5	N/A	N/A	2.25	N/A	20/40	0.5	1/8
C2-SG-5	1.5	N/A	N/A	2.25	N/A	20/40	0.5	1/8

Continued on next page

GSI ENVIRONMENTAL

TABLE A.8.2 (CONTINUED)
SAMPLING POINT COMPLETION DETAILS: CLUSTERS
ESTCP Tier 2 Vapor Screening Study
Buildings 3 and 28
SPAWAR OTC Facility, San Diego, California

Cluster 3								
Groundwater Sampling Points								
C3-PZ-1	14.0	13.5-14	No. 010	2.25	0.75	20/40	0.75	N/A
C3-PZ-2	13.0	12.5-13	No. 010	2.25	0.75	20/40	0.75	N/A
C3-PZ-3	12.0	11.5-12	No. 010	2.25	0.75	20/40	0.75	N/A
C3-PZ-4	11.5	11-11.5	No. 010	2.25	0.75	20/40	0.75	N/A
C3-PZ-5	11.0	10.5-11	No. 010	2.25	0.75	20/40	0.75	N/A
Soil Gas Sampling Points								
C3-SG-1	9.5	N/A	N/A	2.25	N/A	20/40	0.5	1/8
C3-SG-2	11.0	N/A	N/A	2.25	N/A	20/40	0.5	1/8
C3-SG-3	8.0	N/A	N/A	2.25	N/A	20/40	0.5	1/8
C3-SG-4	5.0	N/A	N/A	2.25	N/A	20/40	0.5	1/8
C3-SG-5	2.0	N/A	N/A	2.25	N/A	20/40	0.5	1/8

Notes:
1. Well locations are shown on Figure A.8.1.
2. All locations were completed with a bentonite seal.
3. bgs = Below ground surface.

TABLE A.8.3
DEPTH TO WATER MEASUREMENTS

ESTCP Tier 2 Vapor Screening Study

Buildings 3 and 28
SPAWAR OTC Facility, San Diego, California

Well ID	Installed Total Depth (ft, bgs)	Screen Interval Depth (ft, bgs)	5/13/2011 Depth to Water (ft, bgs)	5/16/2011 Depth to Water (ft, bgs)	Measured Total Depth (ft, bgs)
Cluster 1					
C1-PZ-1	14.0	13.5-14	10.00	10.26	13.9
C1-PZ-2	12.25	11.75-12.25	10.00	10.08	12.3
C1-PZ-3	11.0	10.5-11	10.03	10.10	11.1
C1-PZ-4	10.0	9.5-10	DRY	DRY	10.1
C1-PZ-5	9.5	9-9.5	DRY	DRY	9.7
Cluster 2					
C2-PZ-1	15.0	14.5-15	11.40	11.55	15.0
C2-PZ-2	12.5	12-12.5	11.35	11.40	12.5
C2-PZ-3	12.0	11.5-12	11.34	11.43	12.0
C2-PZ-4	11.0	10.5-11	DRY	DRY	11.1
C2-PZ-5	10.5	10-10.5	DRY	DRY	10.6
Cluster 3					
C3-PZ-1	14.0	13.5-14	11.35	11.62	13.9
C3-PZ-2	13.0	12.5-13	11.35	11.51	13.1
C3-PZ-3	12.0	11.5-12	11.41	11.45	12.0
C3-PZ-4	11.5	11-11.5	DRY	DRY	11.5
C3-PZ-5	11.0	10.5-11	DRY	DRY	11.1

Notes:
1. Well locations are shown on Figure A.8.1.
2. bgs = Below ground surface.

TABLE A.8.4
RESULTS OF GROUNDWATER ANALYSES: COMPOUNDS OF INTEREST

ESTCP Tier 2 Vapor Screening Study

Buildings 3 and 28
SPAWAR OTC Facility, San Diego, California

		DUPLICATE				*DUPLICATE*		
SAMPLE LOCATION:	C1-PZ-1	C1-PZ-1	C1-PZ-2	C1-PZ-3	C2-PZ-1	C2-PZ-1	C2-PZ-2	C2-PZ-3
SCREEN INTERVAL (ft, bgs):	13.5-14	13.5-14	11.75-12.25	10.5-11	14.5-15	14.5-15	12-12.5	11.5-12
SAMPLE DATE:	5/16/2011	5/16/2011	5/16/2011	5/16/2011	5/16/2011	5/16/2011	5/16/2011	5/16/2011
COMPOUND	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Volatile Organic Compounds (VOCs) by USEPA Method 8260B								
Dichloroethene, cis-1,2-	**0.0037**	**0.0034**	**0.0024**	< 0.001	**0.0094**	**0.0083**	**0.0028**	**0.002**
Dichloroethene, trans-1,2-	**0.0034**	**0.003**	< 0.001	< 0.001	**0.021**	**0.017**	**0.0014**	**0.0016**
Toluene	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	< 0.0005	**0.0006**	< 0.0005
Vinyl Chloride	**0.047**	**0.046**	**0.22**	**0.026**	**0.42**	**0.41**	**0.029**	**0.026**

SAMPLE LOCATION:	C3-PZ-1	C3-PZ-2	C3-PZ-3	Trip Blank
SCREEN INTERVAL (ft, bgs):	13.5-14	12.5-13	11.5-12	NA
SAMPLE DATE:	5/16/2011	5/16/2011	5/16/2011	5/16/2011
COMPOUND	mg/L	mg/L	mg/L	mg/L
Volatile Organic Compounds (VOCs) by USEPA Method 8260B				
Dichloroethene, cis-1,2-	< 0.001	< 0.001	< 0.001	< 0.001
Dichloroethene, trans-1,2-	< 0.001	< 0.001	< 0.001	< 0.001
Toluene	< 0.0005	< 0.0005	< 0.0005	< 0.0005
Vinyl Chloride	< 0.001	< 0.001	< 0.001	< 0.001

Notes:
1. Sampling locations are shown on Figure A.8.1.
2. Samples were analyzed by H&P Mobile Geochemistry, Inc. in Carlsbad, California by USEPA Method 8260B.
3. This table summarizes results of detected compounds. Detected analytes are presented in **bold** type.
4. < = Analyte not detected at or above the reporting limit.

TABLE A.8.5
RESULTS OF SOIL GAS ANALYSES: COMPOUNDS OF INTEREST

ESTCP Tier 2 Vapor Screening Study

Buildings 3 and 28
SPAWAR OTC Facility, San Diego, California

SAMPLE LOCATION:	C1-SG-3	C1-SG-4	*DUPLICATE* C1-SG-4	C1-SG-5	C2-SG-2	C2-SG-3	*DUPLICATE* C2-SG-3	C2-SG-4	C2-SG-5
SCREEN INTERVAL (ft, bgs):	7-7.5	4.5-5	4.5-5	1.5-2	10-10.5	7-7.5	7-7.5	4-4.5	1-1.5
SAMPLE DATE:	5/16/2011	5/16/2011	5/16/2011	5/16/2011	5/16/2011	5/16/2011	5/16/2011	5/16/2011	5/16/2011
SAMPLE COLLECTION METHOD:	400-mL Summa	400-mL Summa	400-mL Summa	400-mL Summa	400-mL Summa	400-mL Summa	400-mL Summa	400-mL Summa	400-mL Summa
COMPOUND	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$
Volatile Organic Compounds (VOCs) by USEPA Method TO-15									
Dichloroethene, cis-1,2-	< 4	< 4	< 4	< 4	**950 E**	< 4	< 4	< 4	< 4
Dichloroethene, trans-1,2-	< 8	< 8	< 8	< 8	**1,300 E**	< 8	< 8	< 8	< 8
Toluene	**5.6**	**4.1**	< 3.8	**5.3**	**27**	**13**	**8.2**	**13**	**8.3**
Vinyl Chloride	**5**	< 2.6	< 2.6	< 2.6	**52,000**	**11**	**3.7**	< 2.6	< 2.6
Helium by ASTM D1945M (Results in %)									
Helium (Leak Check Compound)	<1	<1	<1	<1	<1	<1	<1	<1	<1

SAMPLE LOCATION:	C3-SG-1	C3-SG-2	C3-SG-3	C3-SG-4	C3-SG-5
SCREEN INTERVAL (ft, bgs):	9-9.5	10.5-11	7.5-8	4.5-5	1.5-2
SAMPLE DATE:	5/16/2011	5/16/2011	5/16/2011	5/16/2011	5/16/2011
SAMPLE COLLECTION METHOD:	400-mL Summa	400-mL Summa	400-mL Summa	400-mL Summa	400-mL Summa
COMPOUND	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$
Volatile Organic Compounds (VOCs) by USEPA Method TO-15					
Dichloroethene, cis-1,2-	< 4	< 4	< 4	< 4	< 4
Dichloroethene, trans-1,2-	< 8	< 8	< 8	< 8	< 8
Toluene	**18**	**6.3**	**6.3**	**9.5**	**28**
Vinyl Chloride	< 2.6	< 2.6	< 2.6	< 2.6	< 2.6
Helium by ASTM D1945M (Results in %)					
Helium (Leak Check Compound)	<1	<1	<1	<1	<1

Notes:
1. Sampling locations are shown on Figure A.8.1. Soil gas samples were not collected from C1-SG-1, C1-SG-2, C2-SG-1 because water intruded sampling points.
2. Compounds of interest shown in this table include compounds detected in groundwater plus helium (leak tracer).
3. Samples were analyzed by H&P Mobile Geochemistry, Inc. in Carlsbad, California.
4. Detected analytes are presented in **bold** type.
5. < = Analyte not detected at or above the reporting limit.
6. E = The concentration indicated for this analyte is an estimated value above the calibration range of the instrument.

GSI ENVIRONMENTAL

TABLE A.8.6
RESULTS OF SOIL PERMEABILITY TESTING

ESTCP Tier 2 Vapor Screening Study
SPAWAR OTC Facility, San Diego, California

Cluster Location	Sample Point	Air Flow Rate (Q)		Vacuum (P)		Slope of Q vs. P	Permeability (cm2)
		(L/min)	(cc/min)	(in. Hg)	(in. H2O)		
Cluster 1	PZ-4	6	6000	5.25	71	27	7.31E-10
		6.75	6750	11.0	149.6		
		7	7000	14.0	190.4		
		6	6000	10.75	146.2		
		4	4000	3.75	51		
		0.85	850	1.3	17		
		0.4	400	0.6	8.5		
		0.3	300	0.6	8.0		
		0.9	900	1.3	17.5		
		3	3000	5.0	68		
		4.5	4500	17.0	231.2		
	PZ-5	0.1	100	1.2	16.5	8	2.06E-10
		0.12	120	1.8	25		
		1.25	1250	12.0	163.2		
		0.14	140	0.3	3.5		
Cluster 2	PZ-4	1.5	1500	20.0	272	ND	ND
	PZ-5	0.6	600	20.5	279	2	5.26E-11
		0.4	400	19.75	269		
		0.3	300	18.5	252		
		0.2	200	17.25	235		
		0.2	200	15.25	207		
		0.1	100	13.5	184		
		0.2	200	11.5	156		
		0.3	300	11.0	150		
		0.4	400	10.75	146		
		0.65	650	20.0	272		
Cluster 3	PZ-4	0.1	100	1.9	26.5	7.7	2.13E-10
		2	2000	20.0	272		
	PZ-5	6.25	6250	0.1	1.8	1215.0	3.34E-08
		7.75	7750	0.2	2.8		
		10	10000	0.3	3.8		
		13	13000	0.6	8.5		
		10	10000	0.3	3.8		
		8	8000	0.2	2.8		
		6.25	6250	0.1	1.8		
		2.5	2500	0.1	0.8		

Continued on next page

GSI ENVIRONMENTAL

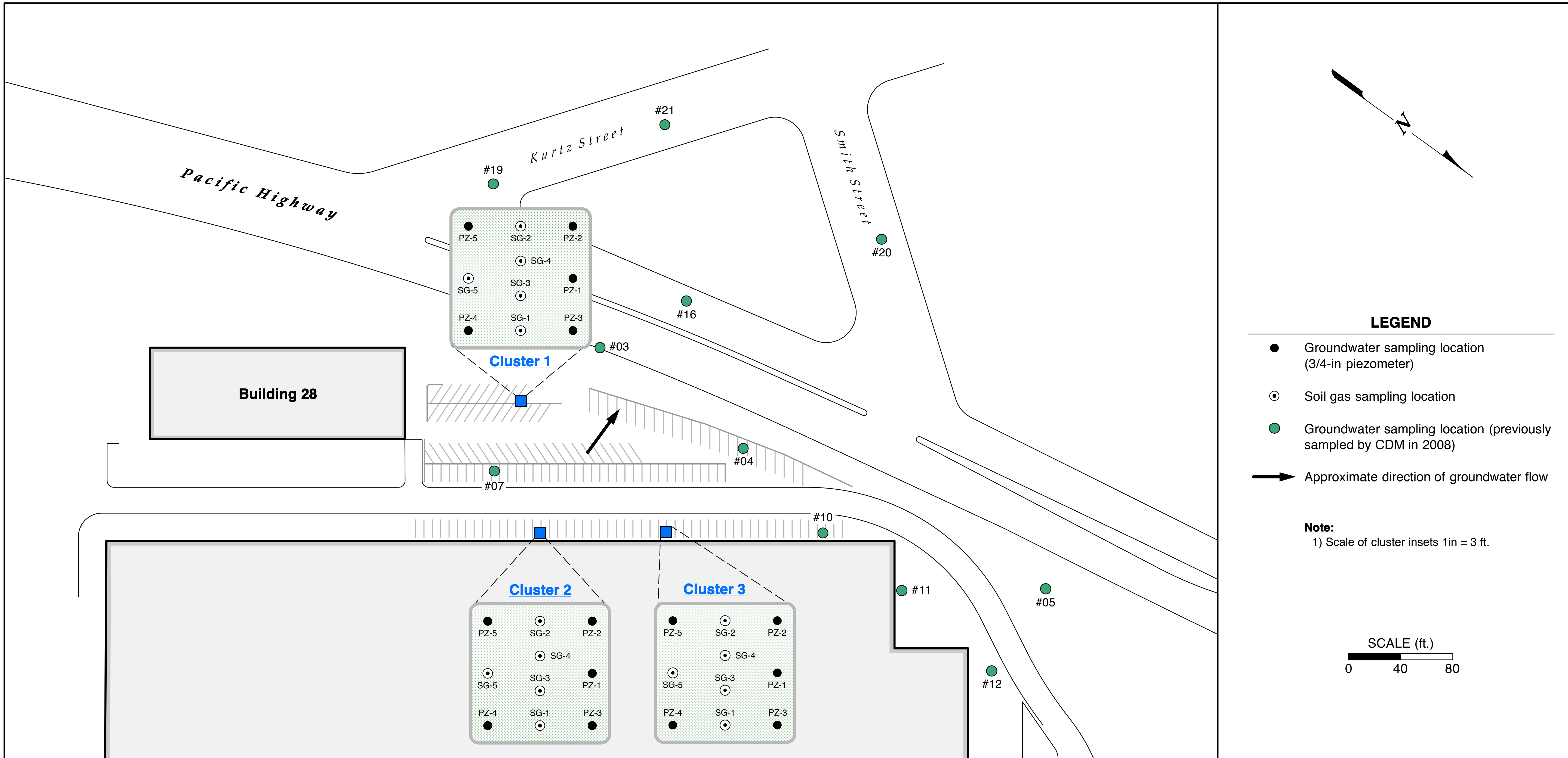
TABLE A.8.6 (CONTINUED)
RESULTS OF SOIL PERMEABILITY TESTING

ESTCP Tier 2 Vapor Screening Study
SPAWAR OTC Facility, San Diego, California

Cluster Location	Sample Point	Air Flow Rate (Q) (L/min)	Air Flow Rate (Q) (cc/min)	Vacuum (P) (in. Hg)	Vacuum (P) (in. H2O)	Slope of Q vs. P	Permeability (cm2)
Cluster 3 (continued).	Measurements by H&P Mobile Geochemistry, Inc.						
*********H&P***********	PZ-5	4	4000	0.3	3.85	511.6	1.41E-08
		3	3000	0.2	2.25		
		2	2000	0.1	1.1		
		1	1000	0.0	0.4		
		2	2000	0.1	1.25		
		3	3000	0.2	2.4		
		4	4000	0.3	4.2		
		10	10000	1.0	14.0		
		14	14000	1.9	26.0		
		10	10000	1.0	14.0		
		5	5000	0.3	4.0		
		4	4000	0.3	3.7		

***Notes*:**
1. ND = Not determined. Only one measurement, due to water in piezometer.

Parameter	Symbol	Value	Units	Basis
Viscosity of air	viscosity	1.73E-04	g/cm-s (poise)	Literature (40 deg. F)
Length: Mont. Well	L	15.2	cm	Screen length for monitoring well points (6 inches)
Diameter: Mont. Well	D	3.2	cm	Inside diameter for monitoring well points
Units Conversion		1.07E-06		From calculation methods sheet
L/D Term: Well Pt		0.1486		Calculated

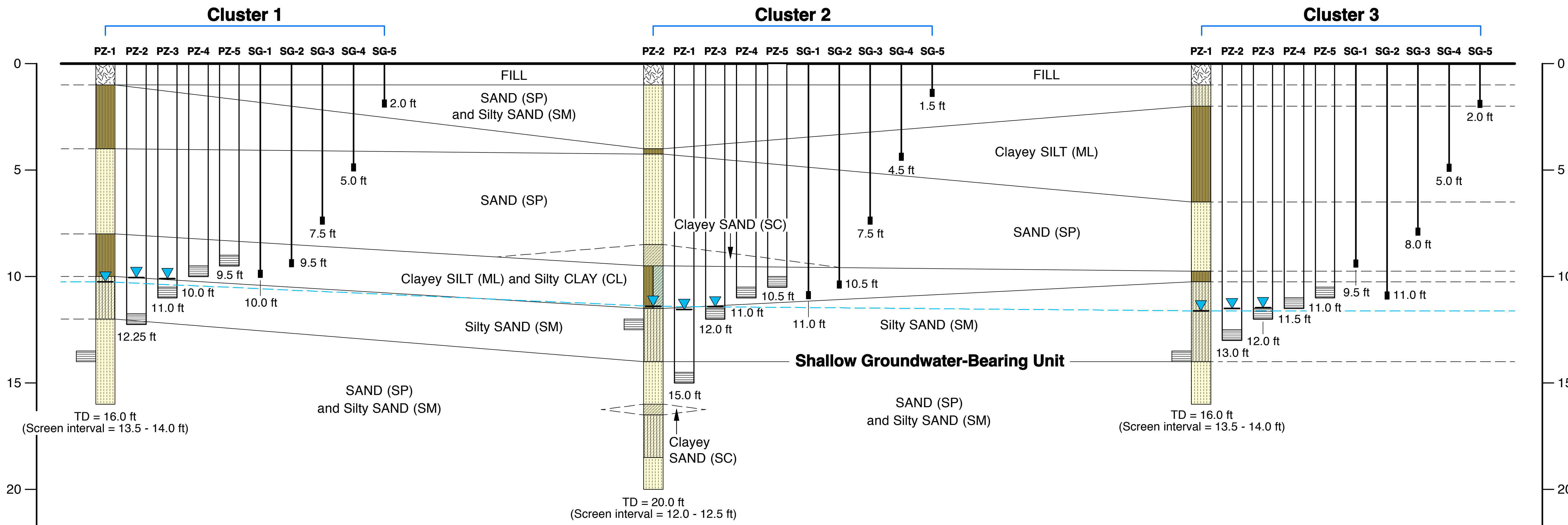


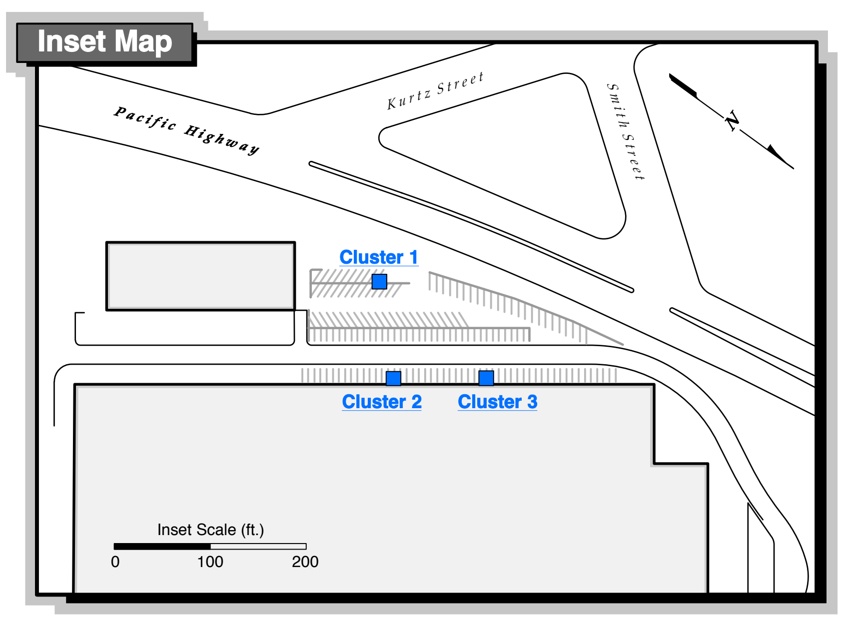
GSI ENVIRONMENTAL

GROUNDWATER AND SOIL GAS SAMPLING LOCATIONS

ESTCP Tier 2 Vapor Screening Study
SPAWAR OTC Facility, San Diego, California

GSI Job No:	G-3213	Drawn By:	DLB
Issued:	18-Nov-11	Chk'd By:	DMB
Revised:	———	Appv'd By:	DMB
Scale:	As Shown		**FIGURE A.8.1**





LEGEND

- FILL
- Silty SAND (SM)
- SAND (SP)
- Clayey SAND (SC)
- Silty CLAY (CL)
- Clayey SILT (ML)
- Screen interval
- Static water level, as measured on 16-May-11
- Potentiometric surface based on static water levels measured on 16-May-11

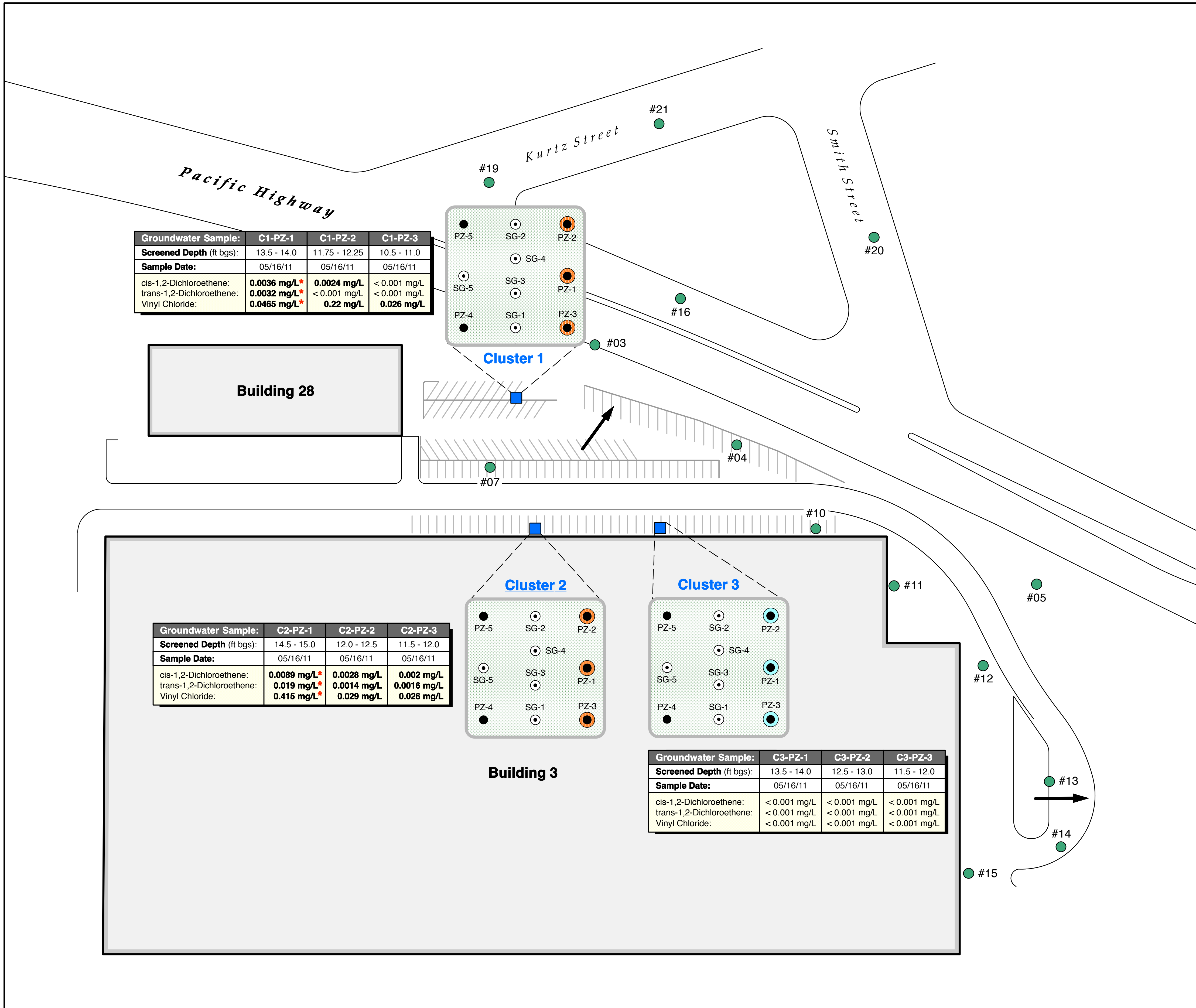
Note: To illustrate the entire lithology at C1-PZ-1, C2-PZ-2, and C3-PZ-1, the screen interval is presented adjacent to the lithology.

GSI ENVIRONMENTAL

CONCEPTUAL CROSS-SECTION OF SUBSURFACE SAMPLE POINTS AND SHALLOW GEOLOGY

ESTCP Tier 2 Vapor Screening Study
SPAWAR OTC Facility, San Diego, California

GSI Job No:	G-3213	Drawn By:	DLB
Issued:	18-Nov-11	Chk'd By:	DMB
Revised:	———	Appv'd By:	DMB
Scale:	As Shown		**FIGURE A.8.2**



Groundwater Sample:	C1-PZ-1	C1-PZ-2	C1-PZ-3
Screened Depth (ft bgs):	13.5 - 14.0	11.75 - 12.25	10.5 - 11.0
Sample Date:	05/16/11	05/16/11	05/16/11
cis-1,2-Dichloroethene:	**0.0036 mg/L***	**0.0024 mg/L**	< 0.001 mg/L
trans-1,2-Dichloroethene:	**0.0032 mg/L***	< 0.001 mg/L	< 0.001 mg/L
Vinyl Chloride:	**0.0465 mg/L***	**0.22 mg/L**	**0.026 mg/L**

Groundwater Sample:	C2-PZ-1	C2-PZ-2	C2-PZ-3
Screened Depth (ft bgs):	14.5 - 15.0	12.0 - 12.5	11.5 - 12.0
Sample Date:	05/16/11	05/16/11	05/16/11
cis-1,2-Dichloroethene:	**0.0089 mg/L***	**0.0028 mg/L**	**0.002 mg/L**
trans-1,2-Dichloroethene:	**0.019 mg/L***	**0.0014 mg/L**	**0.0016 mg/L**
Vinyl Chloride:	**0.415 mg/L***	**0.029 mg/L**	**0.026 mg/L**

Groundwater Sample:	C3-PZ-1	C3-PZ-2	C3-PZ-3
Screened Depth (ft bgs):	13.5 - 14.0	12.5 - 13.0	11.5 - 12.0
Sample Date:	05/16/11	05/16/11	05/16/11
cis-1,2-Dichloroethene:	< 0.001 mg/L	< 0.001 mg/L	< 0.001 mg/L
trans-1,2-Dichloroethene:	< 0.001 mg/L	< 0.001 mg/L	< 0.001 mg/L
Vinyl Chloride:	< 0.001 mg/L	< 0.001 mg/L	< 0.001 mg/L

N

LEGEND

- Groundwater sampling location (3/4-in piezometer)
- Soil gas sampling location
- Groundwater sampling location (previously sampled by CDM in 2008)
- One or more COCs detected above the reporting limit
- COCs not detected
- * Duplicate samples taken; average value shown
- Approximate direction of groundwater flow

Notes:

1) COC = Constituent of Concern (i.e., cis-1,2-DCE, trans-1,2-DCE, and VC)
2) Groundwater samples were analyzed by H&P Mobile Geochemistry, Inc. in Carlsbad, California.
3) cis-1,2-DCE = cis-1,2-Dichloroethene
   trans-1,2-DCE = trans-1,2-Dichloroethene
   VC = Vinyl Chloride
   bgs = Below ground surface
4) Scale of cluster insets 1in = 3 ft.

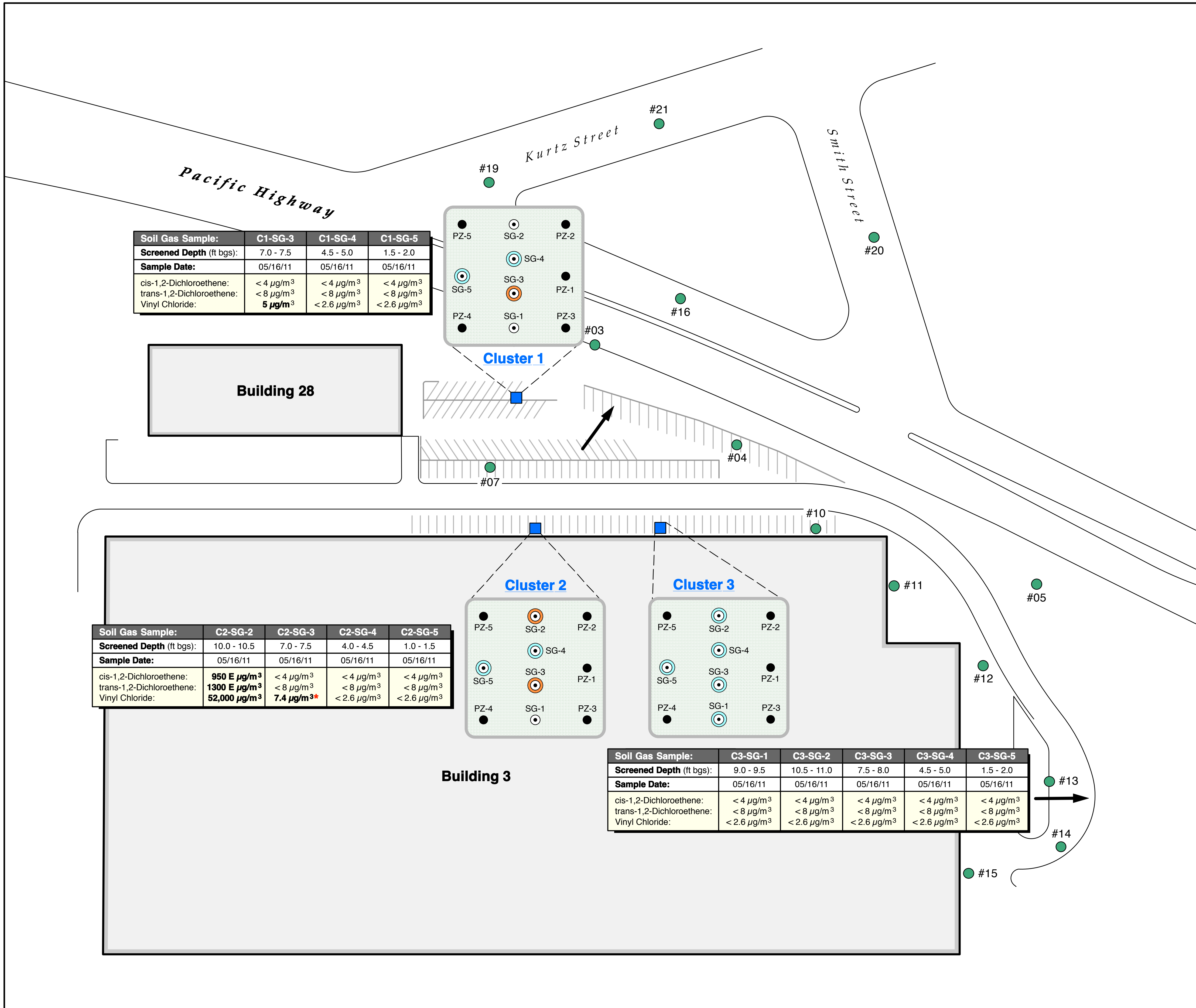
SCALE (ft.)
0 40 80

GSI ENVIRONMENTAL

GROUNDWATER SAMPLING AND TESTING RESULTS

ESTCP Tier 2 Vapor Screening Study
SPAWAR OTC Facility, San Diego, California

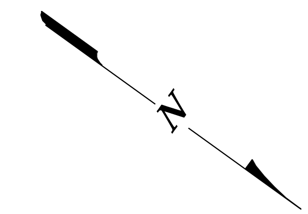
GSI Job No:	G-3213	Drawn By:	DLB
Issued:	18-Nov-11	Chk'd By:	DMB
Revised:	———	Appv'd By:	DMB
Scale:	As Shown		**FIGURE A.8.3**



Soil Gas Sample:	C1-SG-3	C1-SG-4	C1-SG-5
Screened Depth (ft bgs):	7.0 - 7.5	4.5 - 5.0	1.5 - 2.0
Sample Date:	05/16/11	05/16/11	05/16/11
cis-1,2-Dichloroethene:	< 4 μg/m³	< 4 μg/m³	< 4 μg/m³
trans-1,2-Dichloroethene:	< 8 μg/m³	< 8 μg/m³	< 8 μg/m³
Vinyl Chloride:	**5 μg/m³**	< 2.6 μg/m³	< 2.6 μg/m³

Soil Gas Sample:	C2-SG-2	C2-SG-3	C2-SG-4	C2-SG-5
Screened Depth (ft bgs):	10.0 - 10.5	7.0 - 7.5	4.0 - 4.5	1.0 - 1.5
Sample Date:	05/16/11	05/16/11	05/16/11	05/16/11
cis-1,2-Dichloroethene:	**950 E μg/m³**	< 4 μg/m³	< 4 μg/m³	< 4 μg/m³
trans-1,2-Dichloroethene:	**1300 E μg/m³**	< 8 μg/m³	< 8 μg/m³	< 8 μg/m³
Vinyl Chloride:	**52,000 μg/m³**	**7.4 μg/m³***	< 2.6 μg/m³	< 2.6 μg/m³

Soil Gas Sample:	C3-SG-1	C3-SG-2	C3-SG-3	C3-SG-4	C3-SG-5
Screened Depth (ft bgs):	9.0 - 9.5	10.5 - 11.0	7.5 - 8.0	4.5 - 5.0	1.5 - 2.0
Sample Date:	05/16/11	05/16/11	05/16/11	05/16/11	05/16/11
cis-1,2-Dichloroethene:	< 4 μg/m³	< 4 μg/m³	< 4 μg/m³	< 4 μg/m³	< 4 μg/m³
trans-1,2-Dichloroethene:	< 8 μg/m³	< 8 μg/m³	< 8 μg/m³	< 8 μg/m³	< 8 μg/m³
Vinyl Chloride:	< 2.6 μg/m³	< 2.6 μg/m³	< 2.6 μg/m³	< 2.6 μg/m³	< 2.6 μg/m³



LEGEND

- Groundwater sampling location (3/4-in piezometer)
- Soil gas sampling location
- Groundwater sampling location (previously sampled by CDM in 2008)
- One or more COCs detected above the reporting limit
- COCs not detected
- * Duplicate samples taken; average value shown
- Approximate direction of groundwater flow

Notes:

1) COC = Constituent of Concern (i.e., cis-1,2-DCE, trans-1,2-DCE, and VC)
2) No soil gas samples collected from C1-SG-1, C1-SG-2, and C2-SG-1.
3) Soil gas samples were analyzed by H&P Mobile Geochemistry, Inc. in Carslbad, California.
4) cis-1,2-DCE = cis-1,2-Dichloroethene
   trans-1,2-DCE = trans-1,2-Dichloroethene
   VC = Vinyl Chloride
   bgs = Below ground surface
   E = The concentration indicated for this analyte is an estimated value above the calibration range of the instrument.
5) Scale of cluster insets 1in = 3 ft.

SCALE (ft.)
0 40 80

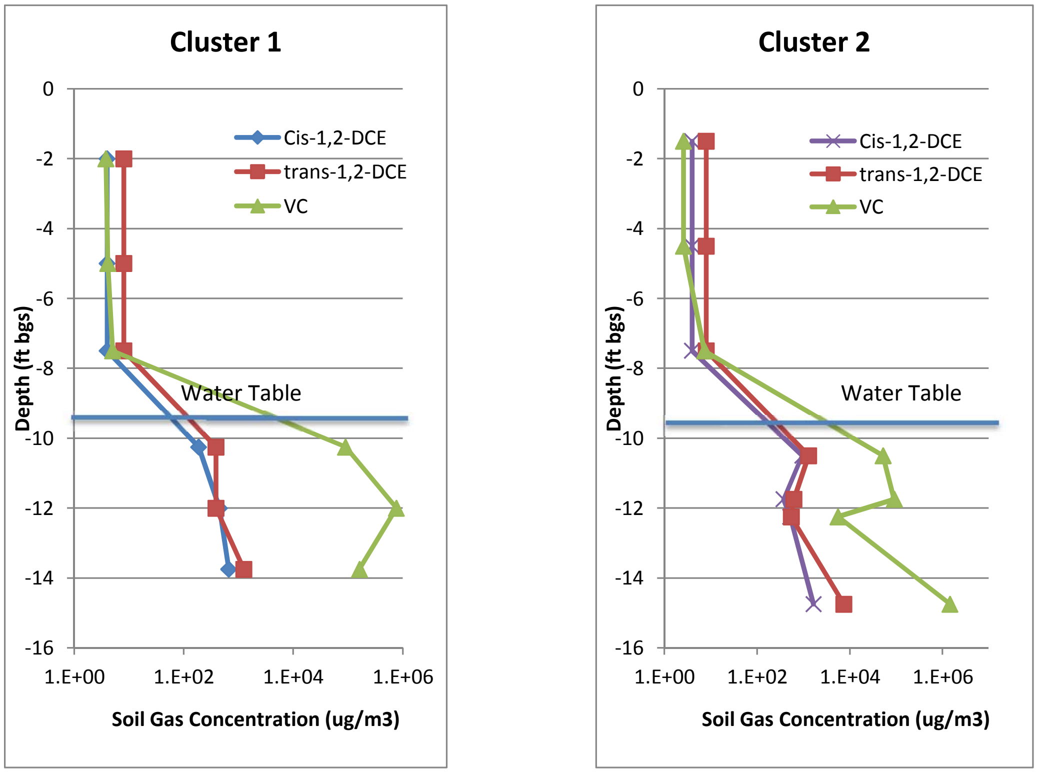
GSI ENVIRONMENTAL

SOIL GAS SAMPLING AND TESTING RESULTS

ESTCP Tier 2 Vapor Screening Study
SPAWAR OTC Facility, San Diego, California

GSI Job No:	G-3213	Drawn By:	DLB
Issued:	18-Nov-11	Chk'd By:	DMB
Revised:	————	Appv'd By:	DMB
Scale:	As Shown		**FIGURE A.8.4**

FIGURE A.8.5
VERTICAL VOC PROFILE
ESTCP Tier 2 Vapor Screening Study
SPAWAR OTC Facility, San Diego, California



* = Concentrations in groundwater (i.e., below the water table) were converted into equivalent soil gas concentrations using Henry's Law assuming equilibrium partitioning.
Note: No COCs detected at Cluster 3.

Environmental Security Technology Certification Program
(ESTCP)

FINAL REPORT

Proposed Tier 2 Screening Criteria and Tier 3 Field Procedures for Evaluation of Vapor Intrusion
ESTCP Project ER-200707

Appendix A.9: NIKE Battery Site PR-58, N. Kingstown, Rhode Island

TABLES

FIGURES

GSI ENVIRONMENTAL

TABLE A.9.1
RESULTS OF GEOTECHNICAL ANALYSES

ESTCP Tier 2 Vapor Screening Study

MW03-11 Well Cluster
Former NIKE Battery Site PR-58, North Kingstown, Rhode Island

Sample ID	Sample Depth	Dry Bulk Density	Fraction Organic Carbon	Volumetric Water Content	Porosity		Intrinsic Permeability to Water	Native Hydraulic Conductivity
					Total	Air Filled	5 PSI Confining Stress	
Units	**ft**	**pcf**	**%**	**%**	**--**	**--**	**cm^2**	**cm/sec**
C1-PZ-2	1-2	100.3	2.2	11.6	0.382	0.266	2.01E-08	1.96E-03
C1-PZ-2	5.25-6.25	98.7	0.4	32.4	0.400	0.076	3.64E-09	3.56E-04
C1-PZ-2	7-8	107.7	0.5	34.0	0.359	0.019	3.98E-10	3.89E-05
C2-PZ-2	1-2	99.1	1.2	9.8	0.400	0.302	4.87E-08	4.76E-03
C2-PZ-2	6-7	116.1	0.7	10.8	0.306	0.198	1.08E-08	1.06E-03
C2-PZ-2	10-11	110.9	0.4	26.0	0.326	0.065	1.14E-08	1.12E-03
C2-PZ-2	16-17	115.2	0.4	26.4	0.314	0.049	4.65E-10	4.54E-05
C3-PZ-2	1-2	109.5	0.5	13.7	0.337	0.200	6.36E-09	6.21E-04
C3-PZ-2	5-6	97	0.4	37.1	0.412	0.040	4.15E-09	4.05E-04
C3-PZ-2	7-8	107.1	0.5	33.6	0.354	0.017	4.98E-08	4.86E-03
C3-PZ-2	10.5-11.5	120.7	0.4	20.8	0.266	0.058	8.03E-09	7.84E-04

Notes:
1. Samples were analyzed by Fugro Consultants, Inc. in Houston, Texas.
2. Dry bulk density, volumetric moisture content, intrinsic permeability, and native hydraulic conductivity determined by ASTM Method D 5084; Fraction Organic Carbon determined by ASTM Method D 2974; and total and air-filled porosity determined by ASTM Method D 854.
3. All sample orientations were vertical.

GSI ENVIRONMENTAL

TABLE A.9.2
SAMPLING POINT COMPLETION DETAILS: CLUSTERS

ESTCP Tier 2 Vapor Screening Study

MW03-11 Well Cluster
Former NIKE Battery Site PR-58, North Kingstown, Rhode Island

Well ID	Installed Total Depth (ft, bgs)	Screen Interval Depth (ft, bgs)	Screen Slot Size (--)	Boring Hole Diameter (inches)	Well Diameter (inches)	Sand Backfill Filter Pack		Tubing Diameter (inches)
						U.S. Mesh Interval	Filter Pack Thickness (ft)	
Cluster 1								
Groundwater Sampling Points								
C1-PZ-1	15	14.5-15	No. 010	3.25	1	20/40	0.75	N/A
C1-PZ-2	12	11.5-12	No. 010	3.25	1	20/40	0.75	N/A
C1-PZ-3	9	8.5-9	No. 010	3.25	1	20/40	0.75	N/A
C1-PZ-4	8	7.5-8	No. 010	3.25	1	20/40	0.75	N/A
C1-PZ-5	7.5	7-7.5	No. 010	3.25	1	20/40	0.75	N/A
Soil Gas Sampling Points								
C1-SG-1	8	N/A	N/A	2.25	N/A	20/40	0.5	1/8
C1-SG-2	7.5	N/A	N/A	2.25	N/A	20/40	0.5	1/8
C1-SG-3	6.5	N/A	N/A	2.25	N/A	20/40	0.5	1/8
C1-SG-4	5	N/A	N/A	2.25	N/A	20/40	0.5	1/8
C1-SG-5	3	N/A	N/A	2.25	N/A	20/40	0.5	1/8
Cluster 2								
Groundwater Sampling Points								
C2-PZ-1	15	14.5-15	No. 010	3.25	1	20/40	0.75	N/A
C2-PZ-2	11	10.5-11	No. 010	3.25	1	20/40	0.75	N/A
C2-PZ-3	9.5	9-9.5	No. 010	3.25	1	20/40	0.75	N/A
C2-PZ-4	8.5	8-8.5	No. 010	3.25	1	20/40	0.75	N/A
C2-PZ-5	8	7.5-8	No. 010	3.25	1	20/40	0.75	N/A
Soil Gas Sampling Points								
C2-SG-1	8.5	N/A	N/A	2.25	N/A	20/40	0.5	1/8
C2-SG-2	8	N/A	N/A	2.25	N/A	20/40	0.5	1/8
C2-SG-3	6	N/A	N/A	2.25	N/A	20/40	0.5	1/8
C2-SG-4	4.5	N/A	N/A	2.25	N/A	20/40	0.5	1/8
C2-SG-5	3	N/A	N/A	2.25	N/A	20/40	0.5	1/8

Continued on next page

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TABLE A.9.2 (CONTINUED)
SAMPLING POINT COMPLETION DETAILS: CLUSTERS

ESTCP Tier 2 Vapor Screening Study

MW03-11 Well Cluster
Former NIKE Facility, North Kingstown, Rhode Island

Well ID	Installed Total Depth (ft, bgs)	Screen Interval Depth (ft, bgs)	Screen Slot Size (--)	Boring Hole Diameter (inches)	Well Diameter (inches)	Sand Backfill Filter Pack		Tubing Diameter (inches)
						U.S. Mesh Interval	Filter Pack Thickness (ft)	
Cluster 3								
Groundwater Sampling Points								
C3-PZ-1	15	14.5-15	No. 010	3.25	1	20/40	0.75	N/A
C3-PZ-2	12	11.5-12	No. 010	3.25	1	20/40	0.75	N/A
C3-PZ-3	9.5	9-9.5	No. 010	3.25	1	20/40	0.75	N/A
C3-PZ-4	8	7.5-8	No. 010	3.25	1	20/40	0.75	N/A
C3-PZ-5	7.5	7-7.5	No. 010	3.25	1	20/40	0.75	N/A
Soil Gas Sampling Points								
C3-SG-1	8	N/A	N/A	2.25	N/A	20/40	0.5	1/8
C3-SG-2	7.5	N/A	N/A	2.25	N/A	20/40	0.5	1/8
C3-SG-3	6	N/A	N/A	2.25	N/A	20/40	0.5	1/8
C3-SG-4	4.5	N/A	N/A	2.25	N/A	20/40	0.5	1/8
C3-SG-5	3	N/A	N/A	2.25	N/A	20/40	0.5	1/8

Notes:
1. Well locations are shown on Figure A.9.1.
2. All locations were completed with a bentonite seal.
3. bgs = Below ground surface.

TABLE A.9.3
DEPTH TO WATER MEASUREMENTS

ESTCP Tier 2 Vapor Screening Study

MW03-11 Well Cluster
Former NIKE Battery Site PR-58, North Kingstown, Rhode Island

Well ID	Installed Total Depth (ft, bgs)	Screen Interval Depth (ft, bgs)	Depth to Water (ft, bgs) 8/2/2011	Measured Total Depth (ft, bgs)
Cluster 1				
C1-PZ-1	15	14.5-15	8.72	14.9
C1-PZ-2	12	11.5-12	8.88	12.5
C1-PZ-3	9	8.5-9	8.90	9
C1-PZ-4	8	7.5-8	DRY	8
C1-PZ-5	7.5	7-7.5	DRY	7.5
Cluster 2				
C2-PZ-1	15	14.5-15	8.87	15.3
C2-PZ-2	11	10.5-11	8.91	11.4
C2-PZ-3	9.5	9-9.5	9.00	9.2
C2-PZ-4	8.5	8-8.5	DRY	8.5
C2-PZ-5	8	7.5-8	DRY	8
Cluster 3				
C3-PZ-1	15	14.5-15	8.11	14.4
C3-PZ-2	12	11.5-12	8.06	11.9
C3-PZ-3	9.5	9-9.5	8.04	9.2
C3-PZ-4	8	7.5-8	DRY	8
C3-PZ-5	7.5	7-7.5	DRY	7.5

Notes:
1. Well locations are shown on Figure A.9.1.
2. bgs = Below ground surface.

TABLE A.9.4
RESULTS OF GROUNDWATER ANALYSES: COMPOUNDS OF INTEREST

ESTCP Tier 2 Vapor Screening Study

MW03-11 Well Cluster
Former NIKE Battery Site PR-58, North Kingstown, Rhode Island

		DUPLICATE				
SAMPLE LOCATION:	C1-PZ-1	C1-PZ-1	C1-PZ-2	C2-PZ-1	C2-PZ-2	C2-PZ-3
SCREEN INTERVAL (ft, bgs):	14.5-15	14.5-15	11.5-12	14.5-15	10.5-11	9-9.5
SAMPLE DATE:	8/1/2011	8/1/2011	8/1/2011	8/1/2011	8/1/2011	8/1/2011
COMPOUND	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Volatile Organic Compounds (VOCs) by USEPA Method 8260B						
Acetone	< 0.00099	< 0.00099	< 0.00099	< 0.00099	< 0.00099	**0.0056**
Benzene	< 0.00008	< 0.00008	< 0.00008	< 0.00008	< 0.00008	< 0.00008
Dichloroethene, cis-1,2-	**0.029**	**0.023**	**0.01**	**0.00021 J**	< 0.00006	< 0.00006
Dichloroethene, trans-1,2-	**0.011**	**0.0098**	**0.0043**	< 0.00009	< 0.00009	< 0.00009
Dichloroethene, Total, 1,2-	**0.04**	**0.033**	**0.014**	< 0.0003	< 0.0003	< 0.0003
Tetrachloroethane, 1,1,2,2-	**0.059**	**0.056**	**0.03**	< 0.00022	< 0.00022	< 0.00022
Tetrachloroethene	**0.0029**	**0.0033**	**0.0024**	< 0.00013	< 0.00013	< 0.00013
Toluene	< 0.00015	< 0.00015	< 0.00015	< 0.00015	< 0.00015	**0.00016 J**
Trichloroethane, 1,1,2-	**0.0025**	**0.0024**	**0.00088 J**	< 0.00028	< 0.00028	< 0.00028
Trichloroethene	**0.13**	**0.14**	**0.061**	**0.003**	**0.0008 J**	< 0.00018

Continued on next page

TABLE A.9.4 (CONTINUED)

RESULTS OF GROUNDWATER ANALYSES: COMPOUNDS OF INTEREST

ESTCP Tier 2 Vapor Screening Study

MW03-11 Well Cluster
Former NIKE Battery Site PR-58, North Kingstown, Rhode Island

SAMPLE LOCATION:	C3-PZ-1	C3-PZ-2	C3-PZ-3	Purge Water	Trip Blank
SCREEN INTERVAL (ft, bgs):	14.5-15	11.5-12	9-9.5	NA	NA
SAMPLE DATE:	8/1/2011	8/1/2011	8/1/2011	8/1/2011	8/1/2011
COMPOUND	mg/L	mg/L	mg/L	mg/L	mg/L
Volatile Organic Compounds (VOCs) by USEPA Method 8260B					
Acetone	< 0.00099	< 0.00099	< 0.00099	**0.0031 J**	< 0.00099
Benzene	< 0.00008	< 0.00008	< 0.00008	**0.00011 J**	< 0.00008
Dichloroethene, cis-1,2-	**0.0051**	**0.0012**	< 0.00006	**0.0031**	< 0.00006
Dichloroethene, trans-1,2-	**0.0023**	**0.00062 J**	< 0.00009	**0.0011 J**	< 0.00009
Dichloroethene, Total, 1,2-	**0.0074**	**0.0018**	< 0.0003	**0.0042**	< 0.0003
Tetrachloroethane, 1,1,2,2-	**0.018**	**0.005**	< 0.00022	**0.013**	< 0.00022
Tetrachloroethene	**0.0012**	**0.00037 J**	< 0.00013	**0.00019 J**	< 0.00013
Toluene	< 0.00015	< 0.00015	< 0.00015	< 0.00015	< 0.00015
Trichloroethane, 1,1,2-	**0.00058 J**	< 0.00028	< 0.00028	**0.00044 J**	< 0.00028
Trichloroethene	**0.038**	**0.012**	**0.002**	**0.015**	< 0.00018

Notes:
1. Sampling locations are shown on Figure A.9.1.
2. Samples were analyzed by TestAmerica Laboratories, Inc. in Houston, Texas by USEPA Method 8260B.
3. This table summarizes the results of detected compounds. Detected analytes are presented in **bold** type.
4. < = Analyte not detected at or above the reporting limit.
   J = Result is less than the reporting limit but greater than or equal to the method detection limit and the concentration is an approximate value.

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TABLE A.9.5
RESULTS OF SOIL GAS ANALYSES: COMPOUNDS OF INTEREST
ESTCP Tier 2 Vapor Screening Study
MW03-11 Well Cluster
Former NIKE Battery Site PR-58, North Kingstown, Rhode Island

SAMPLE LOCATION:	C1-SG-1	C1-SG-2	C1-SG-3	C1-SG-4	C1-SG-5
SCREEN INTERVAL (ft, bgs):	7.5-8	7-7.5	6-6.5	4.5-5	2.5-3
SAMPLE DATE:	8/1/2011	8/1/2011	8/1/2011	8/1/2011	8/1/2011
SAMPLE COLLECTION METHOD:	1-L Summa	1-L Summa	1-L Summa	1-L Summa	1-L Summa
COMPOUND	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$
Volatile Organic Compounds (VOCs) by USEPA Method TO-15					
Acetone	**32**	**41**	<19	<25	<18
Benzene	**9.3**	**8**	**8.5**	**4**	**0.52**
Dichloroethene, cis-1,2-	**19**	**11**	<0.38	<0.5	<0.36
Dichloroethene, trans-1,2-	**37**	**25**	<0.38	<0.5	<0.36
Tetrachloroethane, 1,1,2,2-	**6.9**	**5**	<0.38	<0.5	<0.36
Tetrachloroethene	**90**	**82**	**0.8**	**0.6**	**0.65**
Toluene	**11**	**5.9**	**8.3**	**3.6**	<1.8
Trichloroethane, 1,1,2-	**0.82**	**0.91**	<0.38	<0.5	<0.36
Trichloroethene	**870**	**850**	**1.5**	**1**	<0.36
Helium by Method 3C Modified					
Helium	<6,800	<6,700	<6,300	<8,100	<5,900

		DUPLICATE						
SAMPLE LOCATION:	C2-SG-2	C2-SG-2	C2-SG-3	C2-SG-4	C2-SG-5	C3-SG-3	C3-SG-4	C3-SG-5
SCREEN INTERVAL (ft, bgs):	7.5-8	7.5-8	5.5-6	4-4.5	2.5-3	5.5-6	4-4.5	2.5-3
SAMPLE DATE:	8/2/2011	8/2/2011	8/2/2011	8/2/2011	8/2/2011	8/1/2011	8/1/2011	8/1/2011
SAMPLE COLLECTION METHOD:	1-L Summa	1-L Summa	1-L Summa	1-L Summa	1-L Summa	1-L Summa	1-L Summa	1-L Summa
COMPOUND	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$
Volatile Organic Compounds (VOCs) by USEPA Method TO-15								
Acetone	**35**	**34**	<21	**36**	<18	**29**	<18	<19
Benzene	**9.4**	**6.2**	**1.9**	**3.5**	**1.5**	**9.1**	**3.5**	**0.92**
Dichloroethene, cis-1,2-	<0.39	<0.41	<0.42	<0.35	<0.36	<0.38	<0.37	<0.38
Dichloroethene, trans-1,2-	<0.39	<0.41	<0.42	<0.35	<0.36	<0.38	<0.37	<0.38
Tetrachloroethane, 1,1,2,2-	<0.39	<0.41	<0.42	<0.35	<0.36	<0.38	<0.37	<0.38
Tetrachloroethene	<0.39	**0.92**	<0.42	**0.6**	<0.36	<0.38	<0.37	<0.38
Toluene	**5**	**26**	<2.1	**34**	<1.8	**33**	**6.5**	**3**
Trichloroethane, 1,1,2-	<0.39	<0.41	<0.42	<0.35	<0.36	<0.38	<0.37	<0.38
Trichloroethene	**0.57**	**0.57**	**0.46**	**0.52**	<0.36	**2.1**	**1.2**	**0.54**
Helium by Method 3C Modified								
Helium	<6,300	<6,600	<6,900	<5,700	<5,900	<6,200	<6,000	<6,100

Notes:
1. Sampling locations are shown on Figure A.9.1. Compounds of interest shown in this table include compounds detected in groundwater plus helium (leak tracer).
2. Samples were analyzed by Columbia Analytical Services in Simi Valley, California.
3. Detected analytes are presented in **bold** type; < = Analyte not detected at or above the reporting limit.

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TABLE A.9.6
RESULTS OF SOIL PERMEABILITY TESTING

ESTCP Tier 2 Vapor Screening Study
Former NIKE Battery Site PR-58, North Kingstown, Rhode Islanc

Cluster	Sample	Air Flow Rate (Q)		Vacuum (P)		Slope	Permeability
Location	Point	(L/min)	(cc/min)	(in. Hg)	(in. H2O)	of Q vs. P	(cm2)
Cluster 1	PZ-5	5.0	5000	0.2	3.0	679	1.87E-08
		8.0	8000	0.4	6.0		
		10.0	10000	0.6	8.0		
		12.0	12000	0.8	11.2		
		16.0	16000	1.3	17.0		
		18.0	18000	1.5	21.0		
		20.0	20000	1.9	25.5		
		15.0	15000	1.2	16.0		
		10.0	10000	0.6	8.5		
		7.0	7000	0.4	5.0		
		5.0	5000	0.2	3.1		
	PZ-4	4.75	4750	6.0	81.6	29	8.02E-10
		6.5	6500	9.0	122.4		
		7.5	7500	11.0	149.6		
		8.5	8500	14.2	193.1		
		9.5	9500	18.0	244.8		
		10.0	10000	19.0	258.4		
		8.25	8250	14.5	197.2		
		5.5	5500	9.0	122.4		
Cluster 2	PZ-5	5.0	5000	0.1	1.0	1221.88	3.36E-08
		8.0	8000	0.1	1.5		
		10.0	10000	0.2	2.2		
		14.0	14000	0.3	4.7		
		19.0	19000	0.8	10.2		
		20.0	20000	0.9	12.8		
		11.0	11000	0.2	3.0		
		8.0	8000	0.1	1.7		
		5.0	5000	0.1	1.0		
	PZ-4	5.0	5000	0.1	1.2	1143	3.14E-08
		8.0	8000	0.1	2.0		
		11.0	11000	0.2	3.25		
		14.0	14000	0.4	6.0		
		17.0	17000	0.7	9.0		
		20.0	20000	1.1	14.5		
		17.0	17000	0.7	9.6		
		14.0	14000	0.5	6.4		
		11.0	11000	0.3	3.6		
		8.0	8000	0.2	2.45		
		5.0	5000	0.1	1.4		

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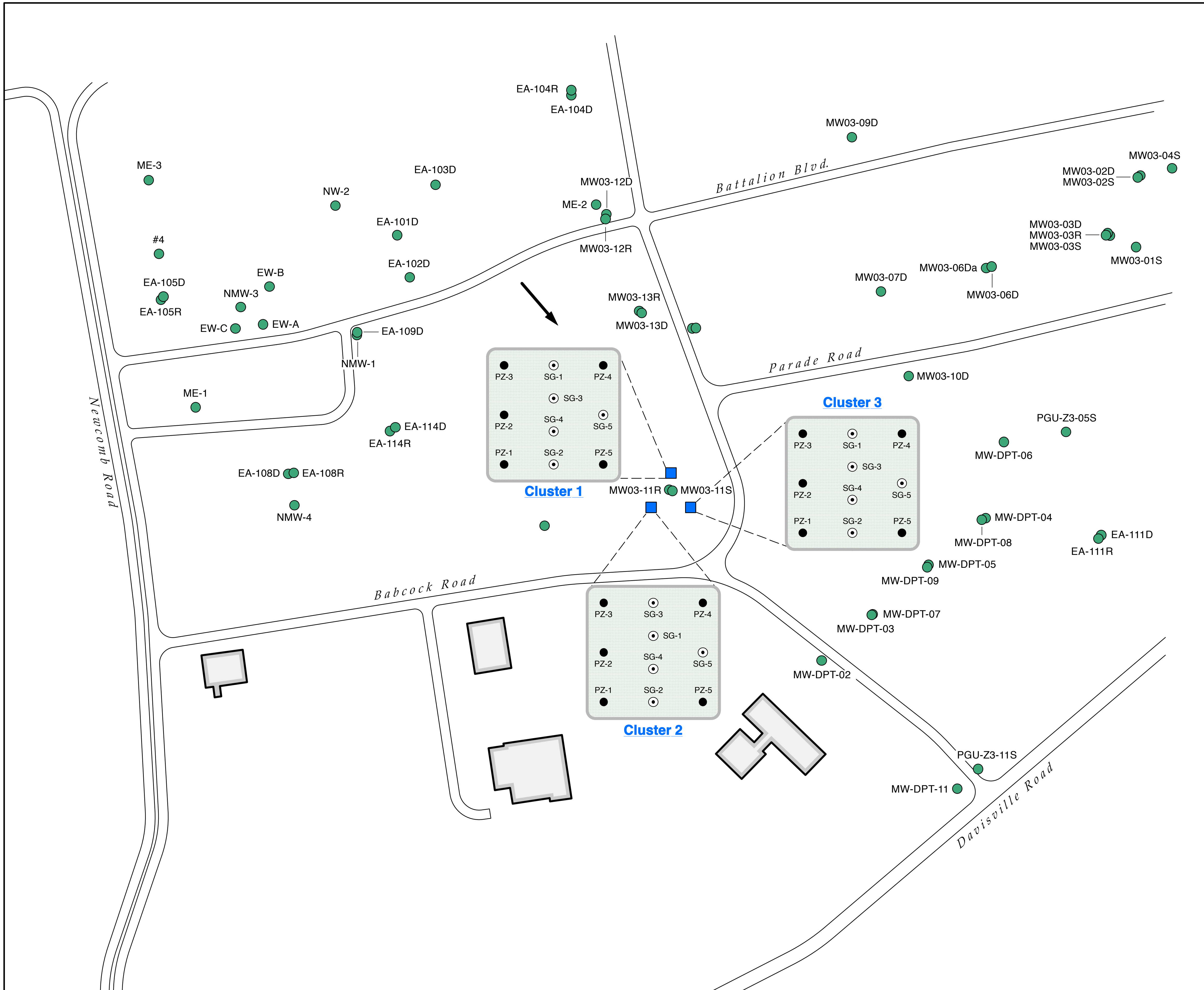
TABLE A.9.6 (CONTINUED)
RESULTS OF SOIL PERMEABILITY TESTING

ESTCP Tier 2 Vapor Screening Study
Former NIKE Battery Site PR-58, North Kingstown, Rhode Islanc

Cluster Location	Sample Point	Air Flow Rate (Q) (L/min)	Air Flow Rate (Q) (cc/min)	Vacuum (P) (in. Hg)	Vacuum (P) (in. H2O)	Slope of Q vs. P	Permeability (cm2)
Cluster 3	PZ-5	5.0	5000	0.1	1.1	993.8	2.73E-08
		7.0	7000	0.1	1.9		
		9.0	9000	0.2	2.7		
		10.0	10000	0.2	3.2		
		14.0	14000	0.5	6.6		
		17.0	17000	0.8	10.7		
		19.0	19000	1.0	14.0		
		20.0	20000	1.2	16.0		
		16.0	16000	0.7	9.2		
		12.0	12000	0.3	4.6		
		10.0	10000	0.2	3.3		
		7.0	7000	0.1	2.0		
		5.0	5000	0.1	1.3		
	PZ-4	5.0	5000	0.2	2.6	620	1.71E-08
		8.0	8000	0.4	5.4		
		10.0	10000	0.5	7.45		
		13.0	13000	1.0	13.0		
		15.0	15000	1.3	17.0		
		19.0	19000	1.7	23.75		
		20.0	20000	1.9	26.5		
		17.0	17000	1.4	19.25		
		14.0	14000	1.0	13.25		
		11.0	11000	0.7	9.0		
		9.0	9000	0.5	6.6		
		8.0	8000	0.4	5.4		
		5.0	5000	0.2	2.6		

Parameter	Symbol	Value	Units	Basis
Viscosity of air	viscosity	1.73E-04	g/cm-s (poise)	Literature (40 deg. F)
Length: Mont. Well	L	15.2	cm	Screen length for monitoring well points (6 inches)
Diameter: Mont. Well	D	3.2	cm	Inside diameter for monitoring well points
Units Conversion		1.07E-06		From calculation methods sheet
L/D Term: Well Pt		0.1486		Calculated



N

LEGEND

- Groundwater sampling location (1-in piezometer)
- Soil gas sampling location
- Existing monitoring well location
- Approximate direction of groundwater flow

Note:
1) Scale of cluster insets 1in = 3 ft.

SCALE (ft.)
0 125 250

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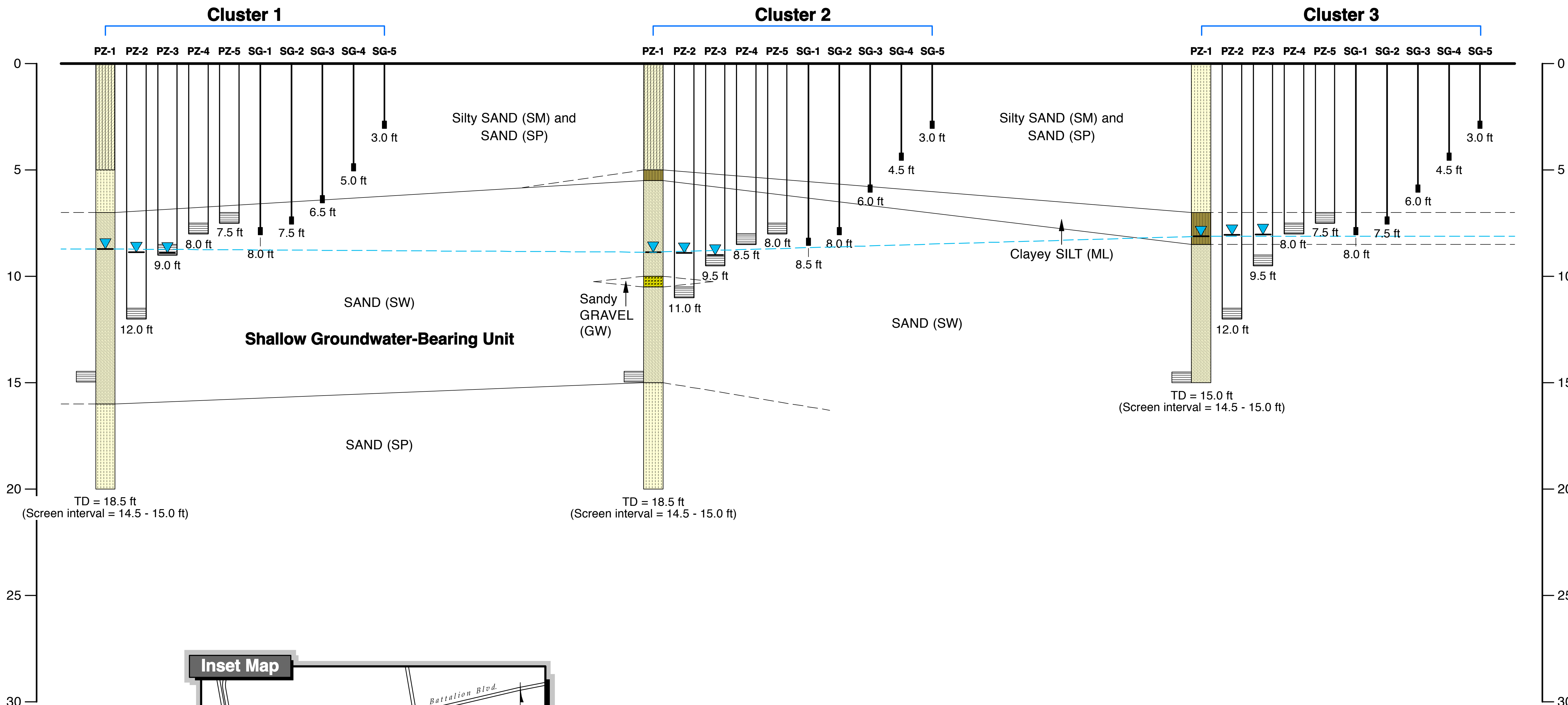
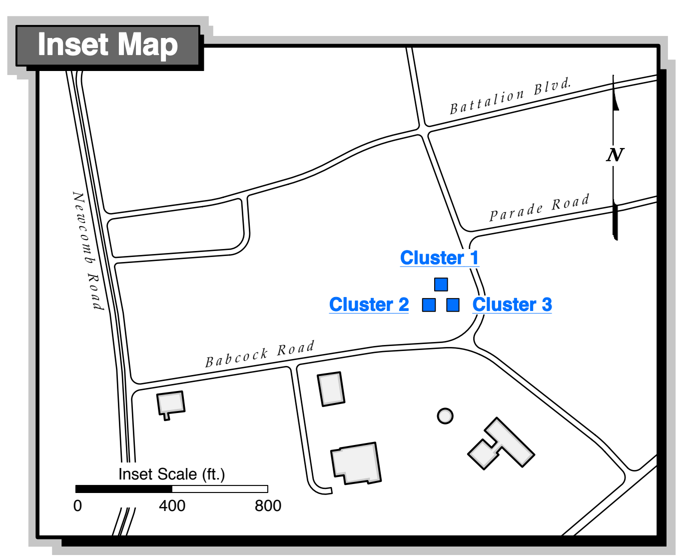
GROUNDWATER AND SOIL GAS SAMPLING LOCATIONS

ESTCP Tier 2 Vapor Screening Study
Former NIKE Battery Site PR-58, North Kingstown, Rhode Island

GSI Job No:	G-3213	Drawn By:	DLB
Issued:	18-Nov-11	Chk'd By:	DMB
Revised:	———	Appv'd By:	DMB
Scale:	As Shown		**FIGURE A.9.1**





LEGEND

Silty SAND (SM)	Screen interval
SAND (SP)	Static water level, as measured on 2-Aug-11
SAND (SW)	Potentiometric surface based on static water levels measured on 2-Aug-11
Sandy GRAVEL (GW)	
Clayey SILT (ML)	

Note: To illustrate the entire lithology at C1-PZ-1, C2-PZ-1, and C3-PZ-1, the screen interval is presented adjacent to the lithology.

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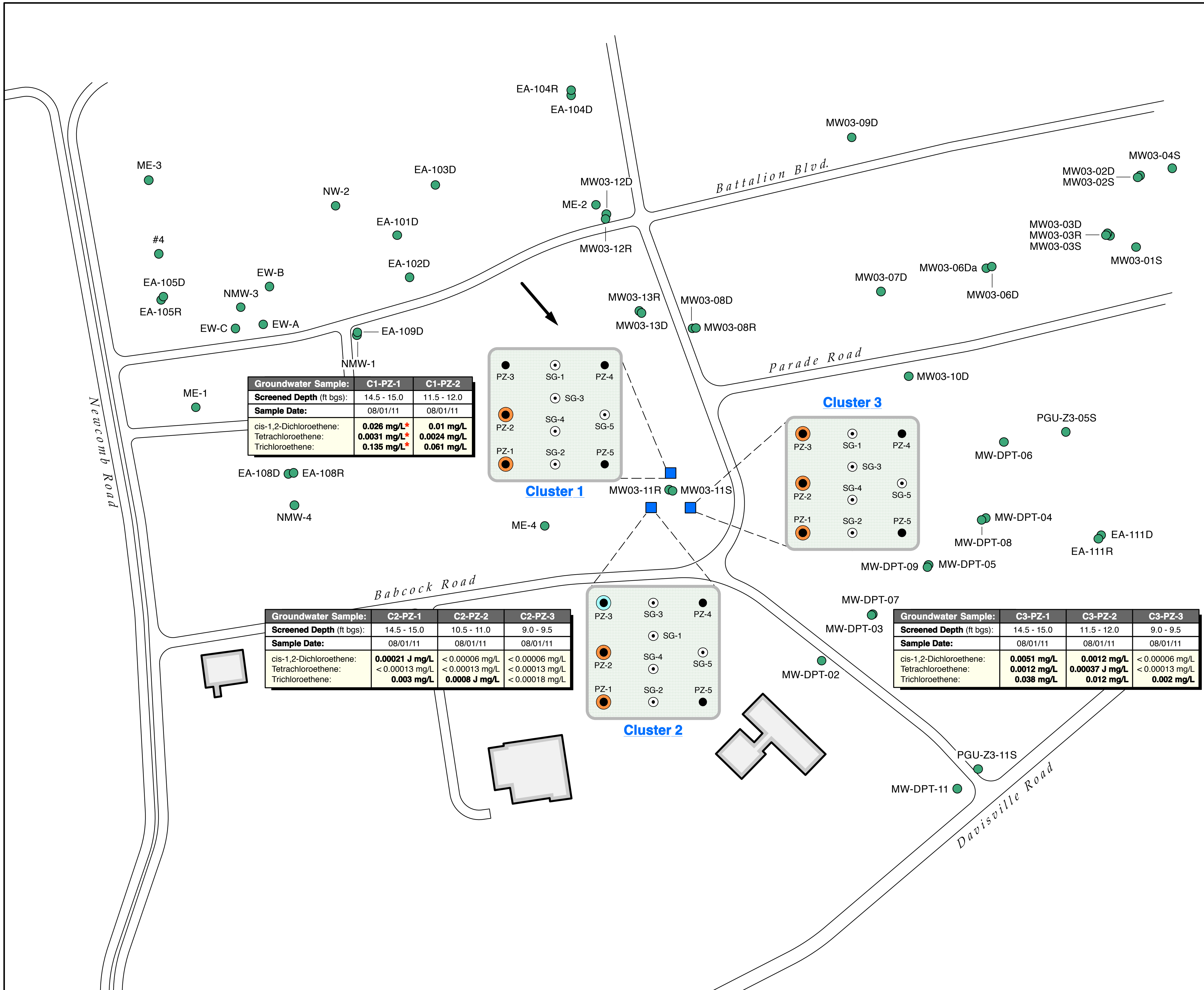
CONCEPTUAL CROSS-SECTION OF SUBSURFACE SAMPLE POINTS AND SHALLOW GEOLOGY

ESTCP Tier 2 Vapor Screening Study
NIKE Battery PR-58 Site, North Kingstown, Rhode Island

GSI Job No:	G-3213	Drawn By:	DLB
Issued:	18-Nov-11	Chk'd By:	DMB
Revised:	———	Appv'd By:	DMB
Scale:	As Shown		**FIGURE A.9.2**



Groundwater Sample:	C1-PZ-1	C1-PZ-2
Screened Depth (ft bgs):	14.5 - 15.0	11.5 - 12.0
Sample Date:	08/01/11	08/01/11
cis-1,2-Dichloroethene:	**0.026 mg/L***	**0.01 mg/L**
Tetrachloroethene:	**0.0031 mg/L***	**0.0024 mg/L**
Trichloroethene:	**0.135 mg/L***	**0.061 mg/L**

Groundwater Sample:	C2-PZ-1	C2-PZ-2	C2-PZ-3
Screened Depth (ft bgs):	14.5 - 15.0	10.5 - 11.0	9.0 - 9.5
Sample Date:	08/01/11	08/01/11	08/01/11
cis-1,2-Dichloroethene:	**0.00021 J mg/L**	< 0.00006 mg/L	< 0.00006 mg/L
Tetrachloroethene:	< 0.00013 mg/L	< 0.00013 mg/L	< 0.00013 mg/L
Trichloroethene:	**0.003 mg/L**	**0.0008 J mg/L**	< 0.00018 mg/L

Groundwater Sample:	C3-PZ-1	C3-PZ-2	C3-PZ-3
Screened Depth (ft bgs):	14.5 - 15.0	11.5 - 12.0	9.0 - 9.5
Sample Date:	08/01/11	08/01/11	08/01/11
cis-1,2-Dichloroethene:	**0.0051 mg/L**	**0.0012 mg/L**	< 0.00006 mg/L
Tetrachloroethene:	**0.0012 mg/L**	**0.00037 J mg/L**	< 0.00013 mg/L
Trichloroethene:	**0.038 mg/L**	**0.012 mg/L**	**0.002 mg/L**

N

LEGEND

- Groundwater sampling location (1-in piezometer)
- Soil gas sampling location
- Existing monitoring well location
- One or more COCs detected above the reporting limit
- COCs not detected
- * Duplicate samples taken; average value shown
- Approximate direction of groundwater flow

Notes:

1) COC = Constituent of Concern (i.e., PCE, TCE, and cis-1,2-DCE)
2) Groundwater samples were analyzed by TestAmerica Laboratories Inc. in Houston,Texas.
3) PCE = Tetrachloroethene
TCE = Trichloroethene
cis-1,2-DCE = cis-1,2-Dichloroethene
bgs = Below ground surface
4) No groundwater sample collected from C1-PZ-3.
5) Scale of cluster insets 1in = 3 ft.

SCALE (ft.)

0 125 250

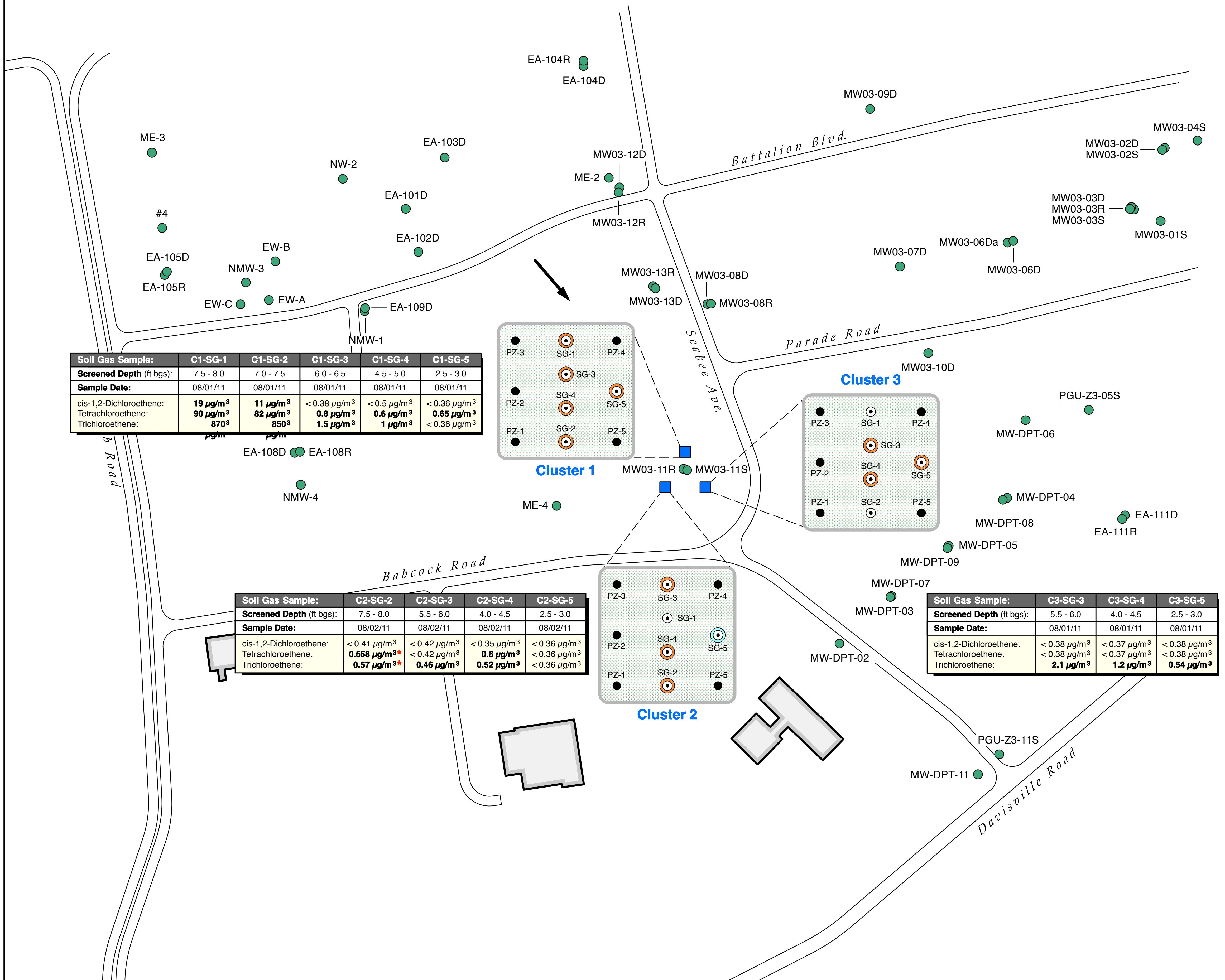
GSI ENVIRONMENTAL

GROUNDWATER SAMPLING AND TESTING RESULTS

ESTCP Tier 2 Vapor Screening Study

Former NIKE Battery Site PR-58, North Kingstown, Rhode Island

GSI Job No:	G-3213	Drawn By:	DLB
Issued:	18-Nov-11	Chk'd By:	DMB
Revised:	———	Appv'd By:	DMB
Scale:	As Shown		**FIGURE A.9.3**



Soil Gas Sample:	C1-SG-1	C1-SG-2	C1-SG-3	C1-SG-4	C1-SG-5
Screened Depth (ft bgs):	7.5 - 8.0	7.0 - 7.5	6.0 - 6.5	4.5 - 5.0	2.5 - 3.0
Sample Date:	08/01/11	08/01/11	08/01/11	08/01/11	08/01/11
cis-1,2-Dichloroethene:	**19 µg/m³**	**11 µg/m³**	< 0.38 µg/m³	< 0.5 µg/m³	< 0.36 µg/m³
Tetrachloroethene:	**90 µg/m³**	**82 µg/m³**	**0.8 µg/m³**	**0.6 µg/m³**	**0.65 µg/m³**
Trichloroethene:	**870 µg/m³**	**850 µg/m³**	**1.5 µg/m³**	**1 µg/m³**	< 0.36 µg/m³

Soil Gas Sample:	C2-SG-2	C2-SG-3	C2-SG-4	C2-SG-5
Screened Depth (ft bgs):	7.5 - 8.0	5.5 - 6.0	4.0 - 4.5	2.5 - 3.0
Sample Date:	08/02/11	08/02/11	08/02/11	08/02/11
cis-1,2-Dichloroethene:	< 0.41 µg/m³	< 0.42 µg/m³	< 0.35 µg/m³	< 0.36 µg/m³
Tetrachloroethene:	**0.558 µg/m³***	< 0.42 µg/m³	**0.6 µg/m³**	< 0.36 µg/m³
Trichloroethene:	**0.57 µg/m³***	**0.46 µg/m³**	**0.52 µg/m³**	< 0.36 µg/m³

Soil Gas Sample:	C3-SG-3	C3-SG-4	C3-SG-5
Screened Depth (ft bgs):	5.5 - 6.0	4.0 - 4.5	2.5 - 3.0
Sample Date:	08/01/11	08/01/11	08/01/11
cis-1,2-Dichloroethene:	< 0.38 µg/m³	< 0.37 µg/m³	< 0.38 µg/m³
Tetrachloroethene:	< 0.38 µg/m³	< 0.37 µg/m³	< 0.38 µg/m³
Trichloroethene:	**2.1 µg/m³**	**1.2 µg/m³**	**0.54 µg/m³**

LEGEND

- Groundwater sampling location (1-in piezometer)
- Soil gas sampling location
- Existing monitoring well location
- One or more COCs detected above the reporting limit
- COCs not detected
- * Duplicate samples taken; average value shown
- Approximate direction of groundwater flow

Notes:

1) COC = Constituent of Concern (i.e., PCE, TCE, and cis-1,2-DCE)
2) No soil gas samples collected from C2-SG-1, C3-SG-1, and C3-SG-2.
3) Soil gas samples were analyzed by Columbia Analytical Services in Simi Valley, California.
4) PCE = Tetrachloroethene
   TCE = Trichloroethene
   cis-1,2-DCE = cis-1,2-Dichloroethene
   bgs = Below ground surface
5) Scale of cluster insets 1in = 3 ft.

SCALE (ft.)
0 125 250

GSI ENVIRONMENTAL

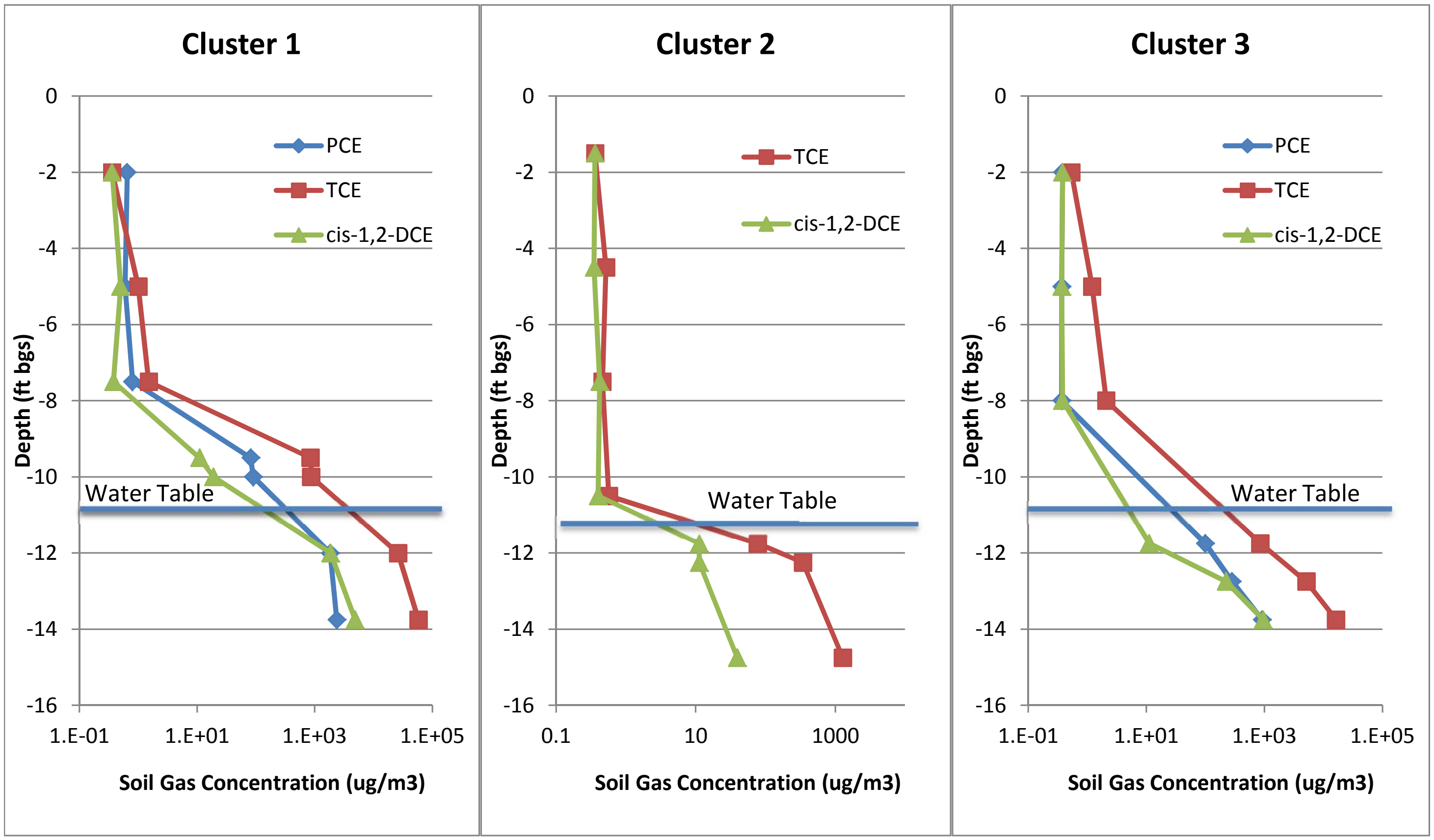
SOIL GAS SAMPLING AND TESTING RESULTS

ESTCP Tier 2 Vapor Screening Study
Former NIKE Battery Site PR-58, North Kingstown, Rhode Island

GSI Job No:	G-3213	Drawn By:	DLB
Issued:	18-Nov-11	Chk'd By:	DMB
Revised:	———	Appv'd By:	DMB
Scale:	As Shown		**FIGURE A.9.4**

GSI Job No. G-3213
Issued: 18 November 2011

FIGURE A.9.5
VERTICAL VOC PROFILE
ESTCP Tier 2 Vapor Screening Study
Former NIKE Battery Site PR-58, North Kingston, Rhode Island



* = Concentrations in groundwater (i.e., below the water table) were converted into equivalent soil gas concentrations using Henry's Law assuming equilibrium partitioning.

Environmental Security Technology Certification Program
(ESTCP)

FINAL REPORT

Proposed Tier 2 Screening Criteria and Tier 3 Field Procedures for Evaluation of Vapor Intrusion
ESTCP Project ER-200707

Appendix A.10: Industrial Site, Southeast Texas

TABLES

FIGURES

GSI ENVIRONMENTAL

TABLE A.10.1
RESULTS OF GEOTECHNICAL ANALYSES

ESTCP Tier 2 Vapor Screening Study

Industrial Site, Southeast Texas

Sample ID	Sample Depth	Dry Bulk Density	Fraction Organic Carbon	Volumetric Water Content	Porosity		Intrinsic Permeability to Water	Native Hydraulic Conductivity
					Total	Air Filled	5 PSI Confining Stress	
Units	**ft**	**pcf**	**%**	**%**	**--**	**--**	**cm^2**	**cm/sec**
C1-PZ-2	0.5-1.5	83.5	2.9	26.4	0.503	0.240	2.71E-09	2.64E-04
C1-PZ-2	8-9	110.5	1.2	21.8	0.343	0.125	1.15E-11	1.13E-06
C1-PZ-2	14.5-15.5	104.6	1.0	36.1	0.376	0.014	3.72E-11	3.63E-06
C1-PZ-2	18-19	104.3	0.6	36.5	0.365	0.000	1.52E-09	1.48E-04
C2-PZ-2	0-1	101.3	2.6	21.6	0.384	0.167	7.36E-10	7.19E-05
C2-PZ-2	4-5	111.5	1.3	17.1	0.335	0.164	3.46E-10	3.38E-05
C2-PZ-2	6-7	112.3	1.5	13.7	0.318	0.180	2.70E-12	2.64E-07
C2-PZ-2	18-19	108.3	0.9	32.9	0.331	0.001	1.87E-11	1.82E-06
C3-PZ-3	2-3	101.9	4.2	18.7	0.380	0.193	9.09E-11	8.88E-06
C3-PZ-3	4-5	121.5	2.5	20.0	0.273	0.073	2.96E-13	2.89E-08
C3-PZ-3	8.25-9.25	92.8	3.4	36.8	0.451	0.083	9.06E-12	8.85E-07
C3-PZ-3	12-13	101.4	2.2	27.8	0.394	0.115	1.66E-09	1.63E-04
C3-PZ-3	16-17	101.3	1.3	37.2	0.384	0.012	4.19E-10	4.09E-05

Notes:
1. Samples were analyzed by Fugro Consultants, Inc. in Houston, Texas.
2. Dry bulk density, volumetric moisture content, intrinsic permeability, and native hydraulic conductivity determined by ASTM Method D 5084; Fraction Organic Carbon determined by ASTM Method D 2974; and total and air-filled porosity determined by ASTM Method D 854.
3. All sample orientations were vertical.

TABLE A.10.2
SAMPLING POINT COMPLETION DETAILS: CLUSTERS

ESTCP Tier 2 Vapor Screening Study

Industrial Site, Southeast Texas

Well ID	Installed Total Depth (ft, bgs)	Screen Interval Depth (ft, bgs)	Screen Slot Size (--)	Boring Hole Diameter (inches)	Well Diameter (inches)	Sand Backfill Filter Pack		Tubing Diameter (inches)
						U.S. Mesh Interval	Filter Pack Thickness (ft)	
Cluster 1								
Groundwater Sampling Points								
C1-PZ-1	20	19.5-20	No. 010	3.25	1	20/40	0.75	N/A
C1-PZ-2	17.5	17-17.5	No. 010	3.25	1	20/40	0.75	N/A
C1-PZ-3	15.5	15-15.5	No. 010	3.25	1	20/40	0.75	N/A
C1-PZ-4	14	13.5-14	No. 010	3.25	1	20/40	0.75	N/A
C1-PZ-5	13	12.5-13	No. 010	3.25	1	20/40	0.75	N/A
Soil Gas Sampling Points								
C1-SG-1	14	N/A	N/A	3.25	N/A	20/40	0.5	1/8
C1-SG-2	12	N/A	N/A	3.25	N/A	20/40	0.5	1/8
C1-SG-3	9	N/A	N/A	3.25	N/A	20/40	0.5	1/8
C1-SG-4	6	N/A	N/A	3.25	N/A	20/40	0.5	1/8
C1-SG-5	3	N/A	N/A	3.25	N/A	20/40	0.5	1/8
Cluster 2								
Groundwater Sampling Points								
C2-PZ-1	23	22.5-23	No. 010	3.25	1	20/40	0.75	N/A
C2-PZ-2	20.5	20-20.5	No. 010	3.25	1	20/40	0.75	N/A
C2-PZ-3	18	17.5-18	No. 010	3.25	1	20/40	0.75	N/A
C2-PZ-4	15.5	15-15.5	No. 010	3.25	1	20/40	0.75	N/A
C2-PZ-5	15	14.5-15	No. 010	3.25	1	20/40	0.75	N/A
Soil Gas Sampling Points								
C2-SG-1	15.5	N/A	N/A	3.25	N/A	20/40	0.5	1/8
C2-SG-2	15	N/A	N/A	3.25	N/A	20/40	0.5	1/8
C2-SG-3	11	N/A	N/A	3.25	N/A	20/40	0.5	1/8
C2-SG-4	7	N/A	N/A	3.25	N/A	20/40	0.5	1/8
C2-SG-5	3	N/A	N/A	3.25	N/A	20/40	0.5	1/8

Continued on next page

GSI ENVIRONMENTAL

TABLE A.10.2 (CONTINUED)

SAMPLING POINT COMPLETION DETAILS: CLUSTERS

ESTCP Tier 2 Vapor Screening Study

Industrial Site, Southeast Texas

Well ID	Installed Total Depth (ft, bgs)	Screen Interval Depth (ft, bgs)	Screen Slot Size (--)	Boring Hole Diameter (inches)	Well Diameter (inches)	Sand Backfill Filter Pack		Tubing Diameter (inches)
						U.S. Mesh Interval	Filter Pack Thickness (ft)	
Cluster 3								
Groundwater Sampling Points								
C3-PZ-1	21.5	21-21.5	No. 010	3.25	1	20/40	0.75	N/A
C3-PZ-2	19.5	19-19.5	No. 010	3.25	1	20/40	0.75	N/A
C3-PZ-3	17.5	17-17.5	No. 010	3.25	1	20/40	0.75	N/A
C3-PZ-4	15	14.5-15	No. 010	3.25	1	20/40	0.75	N/A
C3-PZ-5	14.5	14-14.5	No. 010	3.25	1	20/40	0.75	N/A
Soil Gas Sampling Points								
C3-SG-1	15	N/A	N/A	3.25	N/A	20/40	0.5	1/8
C3-SG-2	14.5	N/A	N/A	3.25	N/A	20/40	0.5	1/8
C3-SG-3	11	N/A	N/A	3.25	N/A	20/40	0.5	1/8
C3-SG-4	7	N/A	N/A	3.25	N/A	20/40	0.5	1/8
C3-SG-5	3	N/A	N/A	3.25	N/A	20/40	0.5	1/8

Notes:
1. Well locations are shown on Figure A.10.1.
2. All locations were completed with a bentonite seal.
3. bgs = Below ground surface.

GSI ENVIRONMENTAL

TABLE A.10.3
DEPTH TO WATER MEASUREMENTS

ESTCP Tier 2 Vapor Screening Study

Industrial Site, Southeast Texas

Well ID	Installed Total Depth (ft, bgs)	Screen Interval Depth (ft, bgs)	10/7/2011 Depth to Water (ft, bgs)	Measured Total Depth (ft, bgs)
Cluster 1				
C1-PZ-1	20	19.5-20	16.10	19.62
C1-PZ-2	17.5	17-17.5	15.97	17.57
C1-PZ-3	15.5	15-15.5	14.77	15.12
C1-PZ-4	14	13.5-14	DRY	13.77
C1-PZ-5	13	12.5-13	DRY	12.95
Cluster 2				
C2-PZ-1	23	22.5-23	16.40	22.27
C2-PZ-2	20.5	20-20.5	16.18	20.37
C2-PZ-3	18	17.5-18	16.20	18.07
C2-PZ-4	15.5	15-15.5	DRY	15.67
C2-PZ-5	15	14.5-15	DRY	14.72
Cluster 3				
C3-PZ-1	21.5	21-21.5	16.85	21.39
C3-PZ-2	19.5	19-19.5	16.82	19.17
C3-PZ-3	17.5	17-17.5	16.81	17.66
C3-PZ-4	15	14.5-15	DAMP	14.77
C3-PZ-5	14.5	14-14.5	DRY	14.37

Notes:
1. Well locations are shown on Figure A.10.1.
2. bgs = Below ground surface.

GSI ENVIRONMENTAL

TABLE A.10.4
RESULTS OF GROUNDWATER ANALYSES: COMPOUNDS OF INTEREST

ESTCP Tier 2 Vapor Screening Study

Industrial Site, Southeast Texas

SAMPLE LOCATION:	C1-PZ-1	C1-PZ-2	C2-PZ-1	C2-PZ-2	C2-PZ-3
SCREEN INTERVAL (ft, bgs):	19.5-20	17-17.5	22.5-23	20-20.5	17.5-18
SAMPLE DATE:	10/10/2011	10/10/2011	10/10/2011	10/10/2011	10/10/2011
COMPOUND	mg/L	mg/L	mg/L	mg/L	mg/L
Volatile Organic Compounds (VOCs) by USEPA Method 8260B					
Acetone	<0.00099	<0.00099	**0.00451 J**	<0.00099	<0.00099
Benzene	**0.00433**	**0.000564 J**	**0.00622**	**0.018**	**0.0088**
Chlorobenzene	<0.00012	<0.00012	<0.00012	**0.000194 J**	<0.00012
Chloroform	**0.0012**	**0.000457 J**	**0.00363**	**0.0066**	**0.00317**
Dichloroethane, 1,1-	**0.0646**	**0.0236**	**0.101**	**0.311**	**0.167**
Dichloroethane, 1,2-	**0.000845 J**	<0.00014	**0.00335**	**0.0101**	**0.00578**
Dichloroethene, 1,1-	**0.279**	**0.0451**	**0.395**	**2.24**	**1.25**
Dichloroethene, cis-1,2-	**0.246**	**0.0548**	**0.379**	**1.56**	**0.857**
Dichloroethene, Total 1,2-	**0.246**	**0.0548**	**0.379**	**1.56**	**0.857**
Tetrachloroethene	**0.0733**	**0.00956**	**0.0604**	**0.724**	**0.177 J**
Toluene	<0.00015	**0.000179 J**	<0.00015	**0.000193 J**	<0.00015
Trichloroethane, 1,1,2-	**0.000598 J**	<0.00028	**0.00635**	**0.014**	**0.00618**
Trichloroethene	**0.0376**	**0.00392**	**0.018**	**0.0939**	**0.0237**
Vinyl Chloride	**0.00317**	**0.00227**	**0.0151**	**0.0831**	**0.0451**
Xylene, o-	**0.000199 J**	<0.00012	**0.000227 J**	**0.00107**	**0.000282 J**
Xylenes, Total	<0.00026	<0.00026	<0.00026	**0.00107**	**0.000282 J**

Continued on next page

TABLE A.10.4 (CONTINUED)

RESULTS OF GROUNDWATER ANALYSES: COMPOUNDS OF INTEREST

ESTCP Tier 2 Vapor Screening Study

Industrial Site, Southeast Texas

		DUPLICATE			
SAMPLE LOCATION:	C3-PZ-1	C3-PZ-1	C3-PZ-2	C3-PZ-3	Trip Blank
SCREEN INTERVAL (ft, bgs):	21-21.5	21-21.5	19-19.5	17-17.5	NA
SAMPLE DATE:	10/10/2011	10/10/2011	10/10/2011	10/10/2011	10/10/2011
COMPOUND	mg/L	mg/L	mg/L	mg/L	mg/L
Volatile Organic Compounds (VOCs) by USEPA Method 8260B					
Acetone	<0.00099	<0.00099	<0.00099	<0.00099	<0.00099
Benzene	**0.0324**	**0.0263**	**0.0183**	**0.0175**	<0.00008
Chlorobenzene	**0.000185 J**	**0.000177 J**	<0.00012	<0.00012	<0.00012
Chloroform	**0.00292**	**0.00246**	**0.00267**	**0.00289**	<0.00013
Dichloroethane, 1,1-	**0.343**	**0.362**	**0.329**	**0.351**	<0.00011
Dichloroethane, 1,2-	**0.0108**	**0.0103**	**0.00989**	**0.0114**	<0.00014
Dichloroethene, 1,1-	**1.81**	**1.92**	**1.87**	**1.67**	<0.00019
Dichloroethene, cis-1,2-	**1.9**	**1.92**	**1.94**	**2.01**	<0.00006
Dichloroethene, Total 1,2-	**1.9**	**1.92**	**1.94**	**2.01**	<0.0003
Tetrachloroethene	**0.284**	**0.34**	**0.081**	**0.195**	<0.00013
Toluene	**0.000232 J**	**0.000229 J**	**0.0002 J**	**0.000183 J**	<0.00015
Trichloroethane, 1,1,2-	**0.00807**	**0.00737**	**0.00676**	**0.00763**	<0.00028
Trichloroethene	**0.0775**	**0.0813**	**0.0358**	**0.0575**	<0.00018
Vinyl Chloride	**0.762**	**0.78**	**1.09**	**0.277**	<0.00011
Xylene, o-	**0.000315 J**	**0.000264 J**	**0.000243 J**	**0.000871 J**	<0.00012
Xylenes, Total	**0.000315 J**	**0.000264 J**	<0.00026	**0.000871 J**	<0.00026

Notes:
1. Sampling locations are shown on Figure A.10.1.
2. Samples were analyzed by TestAmerica Laboratories, Inc. in Houston, Texas by USEPA Method 8260B.
3. This table summarizes the results of detected compounds. Detected analytes are presented in **bold** type.
4. < = Analyte not detected at or above the reporting limit.
J = Result is less than the reporting limit but greater than or equal to the method detection limit and the concentration is an approximate value.

GSI ENVIRONMENTAL

TABLE A.10.5
RESULTS OF SOIL GAS ANALYSES: COMPOUNDS OF INTEREST

ESTCP Tier 2 Vapor Screening Study

Industrial Site, Southeast Texas

SAMPLE LOCATION:	C1-SG-1	C1-SG-2	C1-SG-3	C1-SG-4	C1-SG-5	C2-SG-1	C2-SG-2	C2-SG-3
SCREEN INTERVAL (ft, bgs):	13.5-14	11.5-12	8.5-9	5.5-6	2.5-3	15-15.5	14.5-15	10.5-11
SAMPLE DATE:	10/10/2011	10/10/2011	10/10/2011	10/10/2011	10/10/2011	10/10/2011	10/10/2011	10/10/2011
SAMPLE COLLECTION METHOD:	1-L Summa	1-L Summa	1-L Summa	1-L Summa	1-L Summa	1-L Summa	1-L Summa	1-L Summa
COMPOUND	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$	$\mu g/m^3$
Volatile Organic Compounds (VOCs) by USEPA Method TO-15								
Acetone	<280	<140	<69	**37**	**48**	<8100	<7400	<1700
Benzene	<28	**24**	**37**	**4.8**	<2.4	<810	<740	<170
Chlorobenzene	<28	<14	<6.9	<1.7	<2.4	<810	<740	<170
Chloroform	**31**	**19**	**14**	**1.8**	<2.4	<810	<740	<170
Dichloroethane, 1,1-	**1,200**	**540**	**250**	**7.2**	<2.4	**9,800**	**5,400**	**3,600**
Dichloroethane, 1,2-	<28	<14	<6.9	<1.7	<2.4	<810	<740	<170
Dichloroethene, 1,1-	**4,500**	**2,200**	**1,500**	**140**	<2.4	**140,000**	**92,000**	**66,000 D**
Dichloroethene, cis-1,2-	**900**	**470**	**140**	**3**	<2.4	**48,000**	**28,000**	**17,000**
Tetrachloroethene	**2,300**	**1,300**	**750**	**270**	**99**	**49,000**	**19,000**	**21,000**
Toluene	<28	<14	<6.9	**2.1**	<2.4	<810	<740	<170
Trichloroethane, 1,1,2-	<28	<14	<6.9	<1.7	<2.4	<810	<740	<170
Trichloroethene	**310**	**130**	**65**	**6.6**	<2.4	**4,500**	**1,900**	**1,600**
Vinyl Chloride	<28	**16**	<6.9	<1.7	<2.4	**3,600**	**4,100**	**2,500**
Xylene, o-	<28	<14	<6.9	<1.7	<2.4	<810	<740	<170
Helium by Method 3C Modified								
Helium	< 5,600	< 5,800	< 5,600	< 5,600	< 5,700	< 6,600	< 6,000	< 6,200

Continued on next page

TABLE A.10.5 (CONTINUED)

RESULTS OF SOIL GAS ANALYSES: COMPOUNDS OF INTEREST

ESTCP Tier 2 Vapor Screening Study

Industrial Site, Southeast Texas

							DUPLICATE	
SAMPLE LOCATION:	C2-SG-4	C2-SG-5	C3-SG-1	C3-SG-2	C3-SG-3	C3-SG-4	C3-SG-4	C3-SG-5
SCREEN INTERVAL (ft, bgs):	6.5-7	2.5-3	14.5-15	14-14.5	10.5-11	6.5-7	6.5-7	2.5-3
SAMPLE DATE:	10/10/2011	10/10/2011	10/11/2011	10/11/2011	10/11/2011	10/11/2011	10/11/2011	10/11/2011
SAMPLE COLLECTION METHOD:	1-L Summa	1-L Summa	1-L Summa	1-L Summa	1-L Summa	1-L Summa	1-L Summa	1-L Summa
COMPOUND	µg/m^3	µg/m^3	µg/m^3	µg/m^3	µg/m^3	µg/m^3	µg/m^3	µg/m^3
Volatile Organic Compounds (VOCs) by USEPA Method TO-15								
Acetone	<890	<360	<47000	<36000	<17000	<4600	<4600	<2300
Benzene	<89	<36	<4700	<3600	<1700	<460	<460	<230
Chlorobenzene	<89	<36	<4700	<3600	<1700	<460	<460	<230
Chloroform	<89	**47**	<4700	<3600	<1700	<460	<460	<230
Dichloroethane, 1,1-	**1,100**	**220**	**32,000**	**27,000**	**16,000**	**3,500**	**3,800**	**1,400**
Dichloroethane, 1,2-	<89	<36	<4700	<3600	<1700	<460	<460	<230
Dichloroethene, 1,1-	**22,000 D**	**6,900**	**730,000**	**530,000**	**310,000**	**71,000**	**76,000**	**32,000**
Dichloroethene, cis-1,2-	**4,700**	**650**	**180,000**	**150,000**	**87,000**	**17,000**	**17,000**	**6,100**
Tetrachloroethene	**6,700**	**1,900**	**92,000**	**86,000**	**55,000**	**14,000**	**13,000**	**5,900**
Toluene	<89	<36	<4700	<3600	<1700	<460	<460	<230
Trichloroethane, 1,1,2-	<89	<36	<4700	<3600	<1700	<460	<460	<230
Trichloroethene	**510**	**120**	**16,000**	**14,000**	**8,700**	**2,100**	**2,100**	**830**
Vinyl Chloride	**860**	**130**	**14,000**	**6,100**	**2,800**	**850**	**890**	**430**
Xylene, o-	<89	<36	<4700	<3600	<1700	<460	<460	<230
Helium by Method 3C Modified								
Helium	< 5,900	< 5,800	< 5,700	< 5,900	< 5,600	< 5,600	< 5,700	< 5,600

Notes:
1. Sampling locations are shown on Figure A.10.1.
2. Compounds of interest shown in this table include compounds detected in groundwater plus helium (leak tracer). Average helium release rate: 1 Liter / minute.
3. Samples were analyzed by Columbia Analytical Services in Simi Valley, California.
4. Detected analytes are presented in **bold** type.
5. < = Analyte not detected at or above the reporting limit.
   D = The reported result is from a dilution.

GSI ENVIRONMENTAL

TABLE A.10.6
RESULTS OF SOIL PERMEABILITY TESTING

ESTCP Tier 2 Vapor Screening Study
Industrial Site, Southeast Texas

Cluster Location	Sample Point	Air Flow Rate (Q) (L/min)	Air Flow Rate (Q) (cc/min)	Vacuum (P) (in. Hg)	Vacuum (P) (in. H2O)	Slope of Q vs. P	Permeability (cm2)
Cluster 1	PZ-4	4	4000	0.1	1.5	935	2.57E-08
		6	6000	0.2	2.5		
		8	8000	0.3	4.2		
		10	10000	0.4	5.7		
		12	12000	0.5	6.85		
		14	14000	0.8	11.2		
		20	20000	1.3	18.25		
		14	14000	0.8	11.25		
		12	12000	0.6	7.65		
		10	10000	0.4	5.4		
		8	8000	0.3	4.6		
		6	6000	0.2	2.85		
		4	4000	0.1	1.25		
	PZ-5	4	4000	0.2	3.2	522	1.43E-08
		6	6000	0.5	6.85		
		10	10000	0.9	12.0		
		12	12000	1.4	18.5		
		14	14000	1.6	21.5		
		12	12000	1.5	20.25		
		10	10000	1.1	15.0		
		6	6000	0.5	7.25		
		4	4000	0.3	4.0		
	PZ-3	4	4000	0.6	7.5	68	1.88E-09
		6	6000	1.1	14.75		
		8	8000	1.8	25.0		
		12	12000	1.5	20.4		
		14	14000	2.5	34.0		
		18	18000	6.0	81.6		
		14	14000	10.0	136.0		
		12	12000	9.0	122.4		
		8	8000	2.0	27.2		
		6	6000	1.0	13.75		
		4	4000	0.4	5.5		

Continued on next page

TABLE A.10.6 (CONTINUED)
RESULTS OF SOIL PERMEABILITY TESTING

ESTCP Tier 2 Vapor Screening Study
Industrial Site, Southeast Texas

Cluster Location	Sample Point	Air Flow Rate (Q)		Vacuum (P)		Slope of Q vs. P	Permeability (cm2)
		(L/min)	(cc/min)	(in. Hg)	(in. H2O)		
Cluster 2	PZ-5	4	4000	0.1	2.0	676.93	1.86E-08
		6	6000	0.3	3.6		
		8	8000	0.4	5.7		
		10	10000	0.5	6.25		
		12	12000	0.8	11.2		
		16	16000	1.0	13.0		
		20	20000	1.9	26.5		
		16	16000	1.3	18.0		
		12	12000	0.9	12.0		
		10	10000	0.6	8.5		
		8	8000	0.5	6.4		
		6	6000	0.3	4.2		
		4	4000	0.2	2.4		
	PZ-4	4	4000	0.3	4.2	109	2.99E-09
		6	6000	0.6	8.0		
		8	8000	1.1	15.0		
		10	10000	1.5	20.0		
		12	12000	2.1	28.75		
		16	16000	3.5	47.6		
		17	17000	7.0	95.2		
		16	16000	7.5	102.0		
		12	12000	6.5	88.4		
		10	10000	2.5	34.0		
		8	8000	2.0	27.2		
		6	6000	2.1	28.5		
		4	4000	1.2	16.0		

Continued on next page

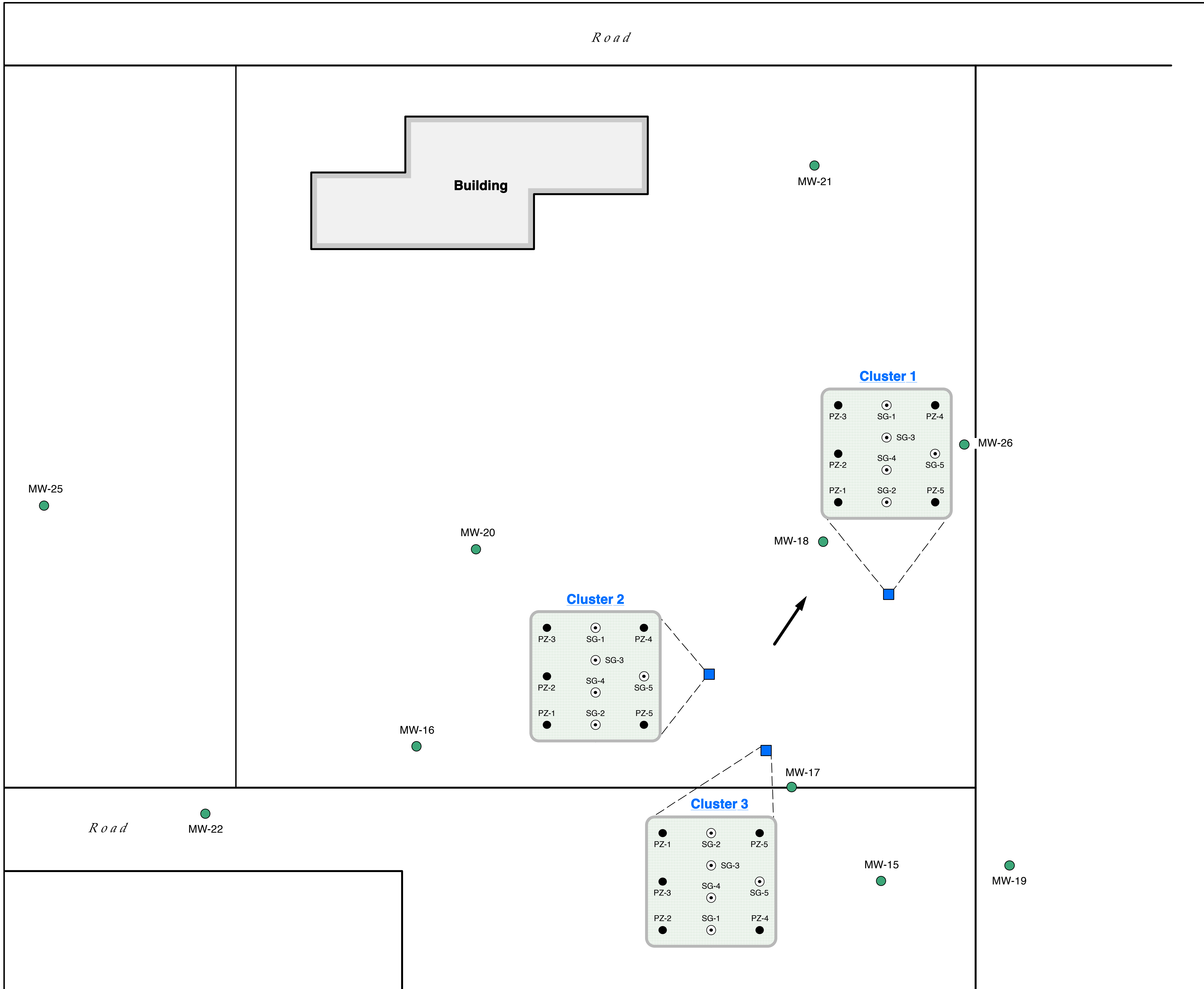
GSI ENVIRONMENTAL

TABLE A.10.6 (CONTINUED)
RESULTS OF SOIL PERMEABILITY TESTING

ESTCP Tier 2 Vapor Screening Study
Industrial Site, Southeast Texas

Cluster Location	Sample Point	Air Flow Rate (Q) (L/min)	Air Flow Rate (Q) (cc/min)	Vacuum (P) (in. Hg)	Vacuum (P) (in. H2O)	Slope of Q vs. P	Permeability (cm2)
Cluster 3	PZ-5	4	4000	0.2	2.8	614	1.69E-08
		6	6000	0.4	5.0		
		8	8000	0.6	8.0		
		10	10000	0.7	9.75		
		14	14000	1.2	16.0		
		16	16000	1.6	21.25		
		18	18000	1.9	26.5		
		16	16000	1.6	21.5		
		14	14000	1.3	17.0		
		10	10000	0.8	10.25		
		8	8000	0.6	8.2		
		6	6000	0.4	5.4		
		4	4000	0.2	3.0		
	PZ-4	4	4000	0.2	3.0	589	1.62E-08
		6	6000	0.5	6.5		
		8	8000	0.8	10.2		
		10	10000	0.8	11.0		
		12	12000	1.0	14.0		
		14	14000	1.3	17.5		
		18	18000	1.7	23.0		
		20	20000	2.1	28.5		
		18	18000	2.1	29.0		
		14	14000	1.8	24.25		
		12	12000	1.3	17.0		
		10	10000	1.0	13.75		
		8	8000	0.7	10.0		
		6	6000	0.6	7.5		
		4	4000	0.3	4.0		

Parameter	Symbol	Value	Units	Basis
Viscosity of air	viscosity	1.73E-04	g/cm-s (poise)	Literature (40 deg. F)
Length: Mont. Well	L	15.2	cm	Screen length for monitoring well points (6 inches)
Diameter: Mont. Well	D	3.2	cm	Inside diameter for monitoring well points
Units Conversion		1.07E-06		From calculation methods sheet
L/D Term: Well Pt		0.1486		Calculated



N

LEGEND

- Groundwater sampling location (1-in piezometer)
- Soil gas sampling location
- Existing monitoring well location
- Approximate direction of groundwater flow

Note:
1) Scale of cluster insets 1in = 3 ft.

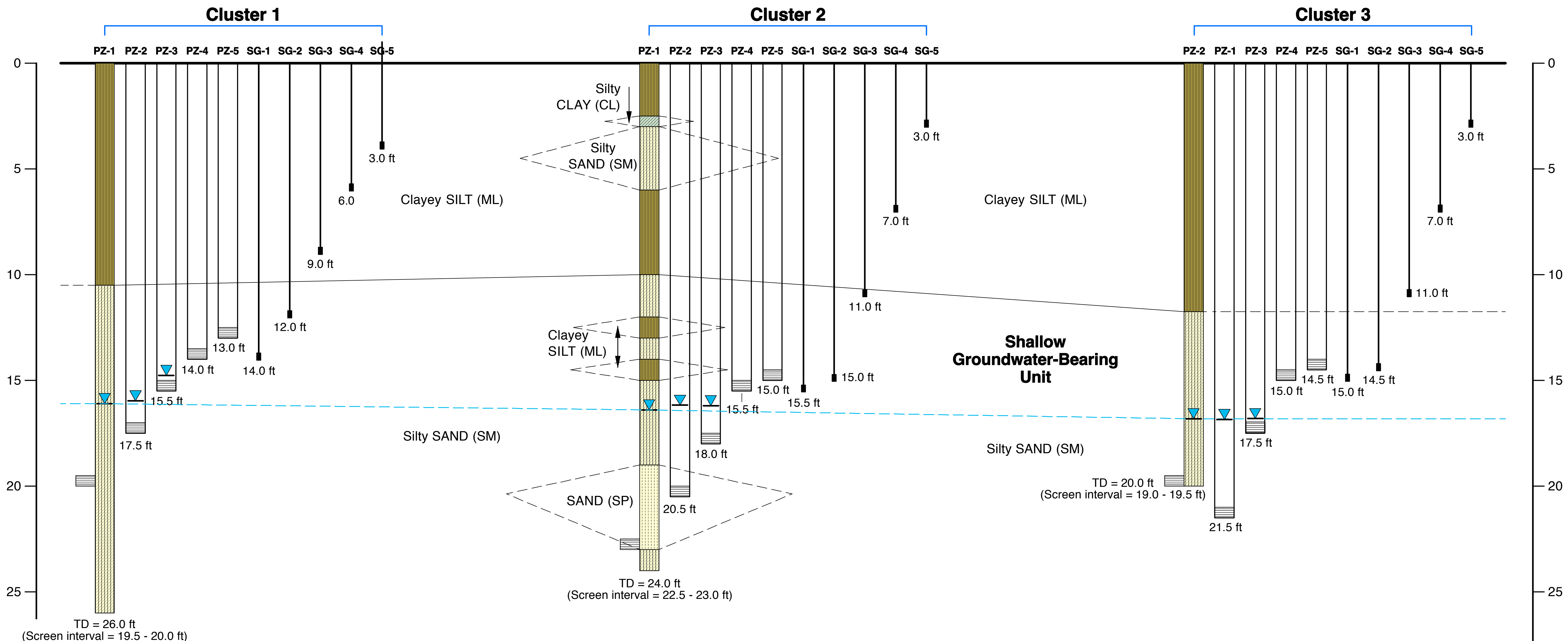
SCALE (ft.)
0 40 80

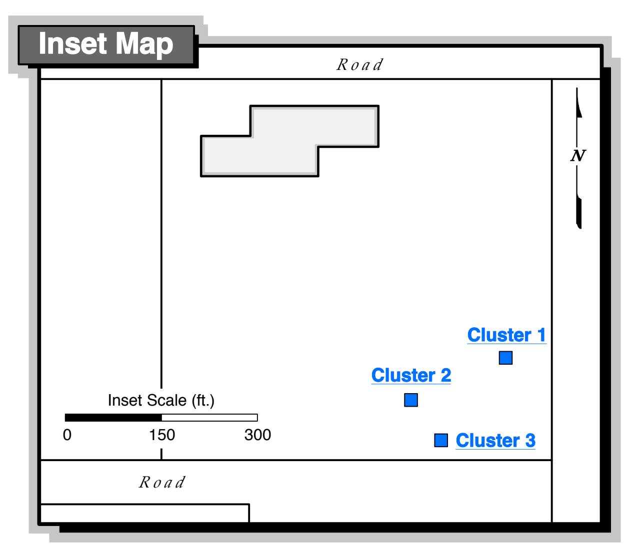
GSI ENVIRONMENTAL

GROUNDWATER AND SOIL GAS SAMPLING LOCATIONS

ESTCP Tier 2 Vapor Screening Study
Industrial Site, Southeast Texas

GSI Job No:	G-3213	Drawn By:	DLB
Issued:	18-Nov-11	Chk'd By:	DMB
Revised:	———	Appv'd By:	DMB
Scale:	As Shown		**FIGURE A.10.1**





LEGEND

Silty SAND (SM)	Screen interval
SAND (SP)	Static water level, as measured on 7-Oct-11
Silty CLAY (CL)	Potentiometric surface based on static water levels measured on 7-Oct-11
Clayey SILT (ML)	

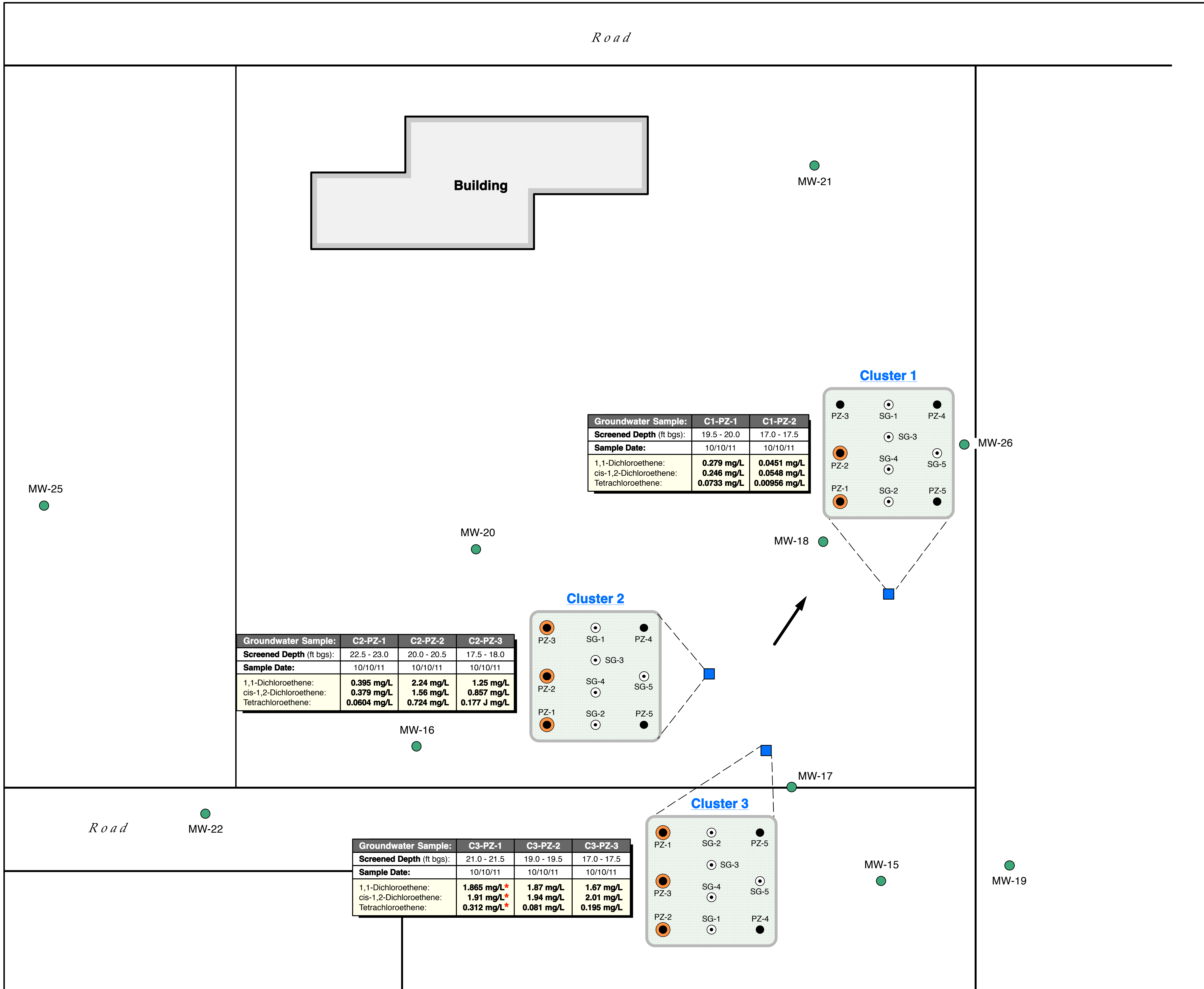
Note: To illustrate the entire lithology at C1-PZ-1, C2-PZ-1, and C3-PZ-2, the screen interval is presented adjacent to the lithology.

GSI ENVIRONMENTAL

CONCEPTUAL CROSS-SECTION OF SUBSURFACE SAMPLE POINTS AND SHALLOW GEOLOGY

ESTCP Tier 2 Vapor Screening Study
Industrial Site, Southeast Texas

GSI Job No:	G-3213	Drawn By:	DLB
Issued:	18-Nov-11	Chk'd By:	DMB
Revised:	———	Appv'd By:	DMB
Scale:	As Shown		**FIGURE A.10.2**



Groundwater Sample:	C1-PZ-1	C1-PZ-2
Screened Depth (ft bgs):	19.5 - 20.0	17.0 - 17.5
Sample Date:	10/10/11	10/10/11
1,1-Dichloroethene:	**0.279 mg/L**	**0.0451 mg/L**
cis-1,2-Dichloroethene:	**0.246 mg/L**	**0.0548 mg/L**
Tetrachloroethene:	**0.0733 mg/L**	**0.00956 mg/L**

Groundwater Sample:	C2-PZ-1	C2-PZ-2	C2-PZ-3
Screened Depth (ft bgs):	22.5 - 23.0	20.0 - 20.5	17.5 - 18.0
Sample Date:	10/10/11	10/10/11	10/10/11
1,1-Dichloroethene:	**0.395 mg/L**	**2.24 mg/L**	**1.25 mg/L**
cis-1,2-Dichloroethene:	**0.379 mg/L**	**1.56 mg/L**	**0.857 mg/L**
Tetrachloroethene:	**0.0604 mg/L**	**0.724 mg/L**	**0.177 J mg/L**

Groundwater Sample:	C3-PZ-1	C3-PZ-2	C3-PZ-3
Screened Depth (ft bgs):	21.0 - 21.5	19.0 - 19.5	17.0 - 17.5
Sample Date:	10/10/11	10/10/11	10/10/11
1,1-Dichloroethene:	**1.865 mg/L***	**1.87 mg/L**	**1.67 mg/L**
cis-1,2-Dichloroethene:	**1.91 mg/L***	**1.94 mg/L**	**2.01 mg/L**
Tetrachloroethene:	**0.312 mg/L***	**0.081 mg/L**	**0.195 mg/L**

N

LEGEND

- Groundwater sampling location (1-in piezometer)
- Soil gas sampling location
- Existing monitoring well location
- One or more COCs detected above the reporting limit
- COCs not detected
- * Duplicate samples taken; average value shown
- Approximate direction of groundwater flow

Notes:

1) COC = Constituent of Concern (i.e., 1,1-DCE, cis-1,2-DCE, and PCE)
2) Groundwater samples were analyzed by TestAmerica Laboratories Inc. in Houston, Texas.
3) No groundwater sample collected from C1-PZ-3.
4) 1,1-DCE = 1,1-Dichloroethene
   cis-1,2-DCE = cis-1,2-Dichloroethene
   PCE = Tetrachloroethene
   J = Result is less than the reporting limit, but greater than or equal to the method detection limit and the concentration is an approximate value.
   bgs = Below ground surface
5) Scale of cluster insets 1in = 3 ft.

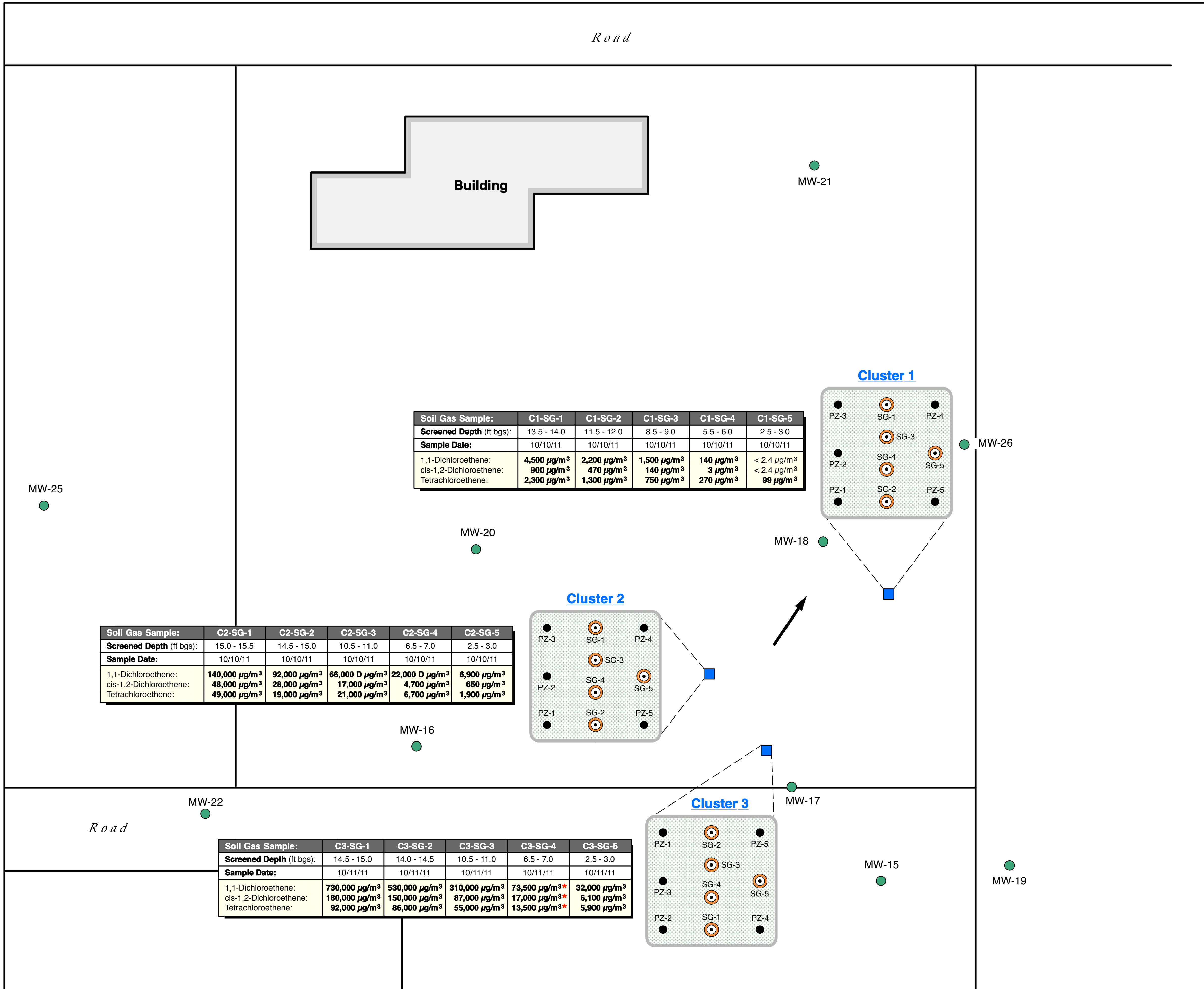
SCALE (ft.)
0 40 80

GSI ENVIRONMENTAL

GROUNDWATER SAMPLING AND TESTING RESULTS

ESTCP Tier 2 Vapor Screening Study
Industrial Site, Southeast Texas

GSI Job No:	G-3213	Drawn By:	DLB
Issued:	18-Nov-11	Chk'd By:	DMB
Revised:	———	Appv'd By:	DMB
Scale:	As Shown		**FIGURE A.10.3**



Soil Gas Sample:	C1-SG-1	C1-SG-2	C1-SG-3	C1-SG-4	C1-SG-5
Screened Depth (ft bgs):	13.5 - 14.0	11.5 - 12.0	8.5 - 9.0	5.5 - 6.0	2.5 - 3.0
Sample Date:	10/10/11	10/10/11	10/10/11	10/10/11	10/10/11
1,1-Dichloroethene:	**4,500 μg/m^3**	**2,200 μg/m^3**	**1,500 μg/m^3**	**140 μg/m^3**	< 2.4 μg/m^3
cis-1,2-Dichloroethene:	**900 μg/m^3**	**470 μg/m^3**	**140 μg/m^3**	**3 μg/m^3**	< 2.4 μg/m^3
Tetrachloroethene:	**2,300 μg/m^3**	**1,300 μg/m^3**	**750 μg/m^3**	**270 μg/m^3**	**99 μg/m^3**

Soil Gas Sample:	C2-SG-1	C2-SG-2	C2-SG-3	C2-SG-4	C2-SG-5
Screened Depth (ft bgs):	15.0 - 15.5	14.5 - 15.0	10.5 - 11.0	6.5 - 7.0	2.5 - 3.0
Sample Date:	10/10/11	10/10/11	10/10/11	10/10/11	10/10/11
1,1-Dichloroethene:	**140,000 μg/m^3**	**92,000 μg/m^3**	**66,000 D μg/m^3**	**22,000 D μg/m^3**	**6,900 μg/m^3**
cis-1,2-Dichloroethene:	**48,000 μg/m^3**	**28,000 μg/m^3**	**17,000 μg/m^3**	**4,700 μg/m^3**	**650 μg/m^3**
Tetrachloroethene:	**49,000 μg/m^3**	**19,000 μg/m^3**	**21,000 μg/m^3**	**6,700 μg/m^3**	**1,900 μg/m^3**

Soil Gas Sample:	C3-SG-1	C3-SG-2	C3-SG-3	C3-SG-4	C3-SG-5
Screened Depth (ft bgs):	14.5 - 15.0	14.0 - 14.5	10.5 - 11.0	6.5 - 7.0	2.5 - 3.0
Sample Date:	10/11/11	10/11/11	10/11/11	10/11/11	10/11/11
1,1-Dichloroethene:	**730,000 μg/m^3**	**530,000 μg/m^3**	**310,000 μg/m^3**	**73,500 μg/m^3***	**32,000 μg/m^3**
cis-1,2-Dichloroethene:	**180,000 μg/m^3**	**150,000 μg/m^3**	**87,000 μg/m^3**	**17,000 μg/m^3***	**6,100 μg/m^3**
Tetrachloroethene:	**92,000 μg/m^3**	**86,000 μg/m^3**	**55,000 μg/m^3**	**13,500 μg/m^3***	**5,900 μg/m^3**

N

LEGEND

- ● Groundwater sampling location (1-in piezometer)
- ⊙ Soil gas sampling location
- ● Existing monitoring well location
- ● One or more COCs detected above the reporting limit
- ○ COCs not detected
- * Duplicate samples taken; average value shown
- → Approximate direction of groundwater flow

Notes:

1) COC = Constituent of Concern (i.e., 1,1-DCE, cis-1,2-DCE, and PCE)

2) Soil gas samples were analyzed by Columbia Analytical Services in Simi Valley, California.

3) 1,1-DCE = 1,1-Dichloroethene
cis-1,2-DCE = cis-1,2-Dichloroethene
PCE = Tetrachloroethene
bgs = Below ground surface
D = The reported result is from a dilution.

4) Scale of cluster insets 1in = 3 ft.

SCALE (ft.)
0 40 80

GSI ENVIRONMENTAL

SOIL GAS SAMPLING AND TESTING RESULTS

ESTCP Tier 2 Vapor Screening Study
Industrial Site, Southeast Texas

GSI Job No:	G-3213	Drawn By:	DLB
Issued:	18-Nov-11	Chk'd By:	DMB
Revised:	______	Appv'd By:	DMB
Scale:	As Shown		**FIGURE A.10.4**

GSI Job No. G-3213
Issued: 18 November 2011
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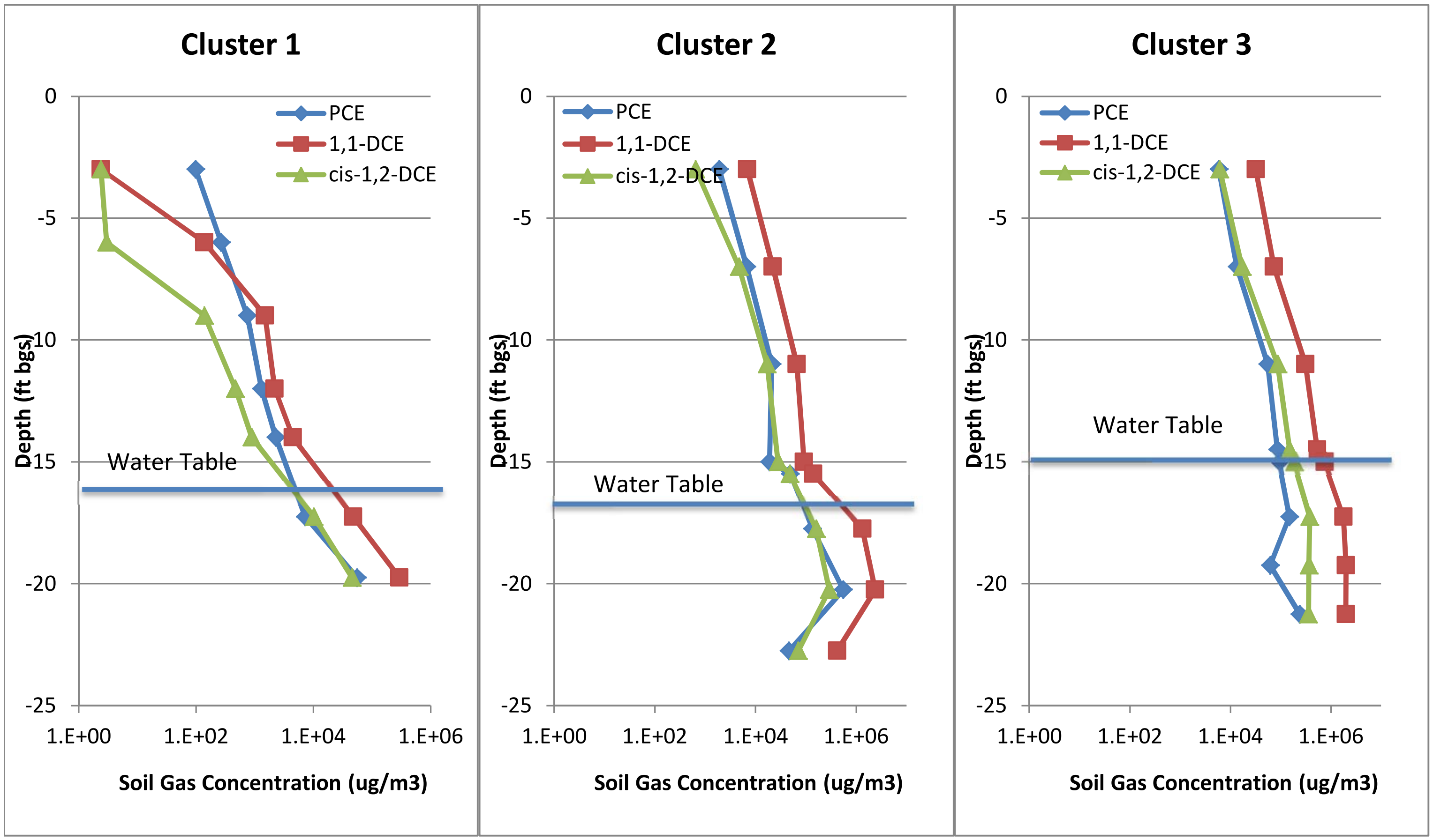
FIGURE A.10.5

VERTICAL VOC PROFILE

ESTCP Tier 2 Vapor Screening Study

Industrial Site, Southeast Texas



* = Concentrations in groundwater (i.e., below the water table) were converted into equivalent soil gas concentrations using Henry's Law assuming equilibrium partitioning.

Environmental Security Technology Certification Program
(ESTCP)

FINAL REPORT

Proposed Tier 2 Screening Criteria and Tier 3 Field Procedures for Evaluation of Vapor Intrusion
ESTCP Project ER-200707

Appendix B: Calculation of Air Exchange Rates

APPENDIX B: CALCULATION OF AIR EXCHANGE RATES

Proposed Tier 2 Screening Criteria and Tier 3 Field Procedures for Evaluation of Vapor Intrusion
ESTCP Project ER-0707

Appendix B.1: Travis AFB

$$\text{ER (day}^{-1}\text{)} = \frac{\text{Fresh Air Entry Rate (ft}^3\text{/day)}}{\text{Building Volume(ft}^3\text{)}}$$

$$\text{Fresh Air Entry Rate (ft}^3\text{/day)} = \frac{\text{Tracer Gas Release Rate (ft}^3\text{/day)}}{\text{Measured Tracer Gas Concentration (fraction)}}$$

Where:

ER = Building air exchange rate (day^{-1})
Fresh Air Entry Rate = Rate at which ambient air enters building (ft^3/day)
Tracer Gas Release Rate = Rate at which SF_6 tracer gas was released during test
76 ml/min rotameter reading (sapphire bead) = 23.7 ml/min flow rate
(23.7 mL 1% SF_6/min = 0.237 mL SF_6/min x 1440 min/day x 3.53 x 10^{-5} ft^3/mL
= 0.0120 ft^3 SF_6/day)

Measured Tracer Gas Concentration (Negative Pressure)
= 92 ug/m3 = 15.4 ppbv = 15.4 x 10^{-9}

Measured Tracer Gas Concentration (Positive Pressure)
= 56 ug/m3 = 9.4 ppbv = 9.4 x 10^{-9}

Building Volume = Volume of demonstration building
(50 ft x 32 ft x 10 ft = 16,000 ft^3)

Example Calculation: Building Air Exchange Rate
Fresh Air Entry Rate = (0.0120 ft^3/day)/15.4 x 10^{-9} = 779,000 ft^3/day
ER = 779,000 ft^3/day / 16,000 ft^3 = 49 day^{-1}

Calculation Results: Building Air Exchange Rate

Test Building	Fresh Air Entry Rate (ft^3/day)	Air Exchange Rate (day^{-1})
Building 828: Negative Pressure	779,000	49
Building 828: Positive Pressure	1,276,000	80

APPENDIX B: CALCULATION OF AIR EXCHANGE RATES

Proposed Tier 2 Screening Criteria and Tier 3 Field Procedures for Evaluation of Vapor Intrusion
ESTCP Project ER-0707

Appendix B.2 Jacksonville NAS

$$\text{ER (day}^{-1}) = \frac{\text{Fresh Air Entry Rate (ft}^3\text{/day)}}{\text{Building Volume(ft}^3)}$$

$$\text{Fresh Air Entry Rate (ft}^3\text{/day)} = \frac{\text{Tracer Gas Release Rate (ft}^3\text{/day)}}{\text{Measured Tracer Gas Concentration (fraction)}}$$

Where:

ER = Building air exchange rate (day^{-1})
Fresh Air Entry Rate = Rate at which ambient air enters building (ft^3/day)
Tracer Gas Release Rate = Rate at which SF_6 tracer gas was released during test
142 ml/min rotameter reading (sapphire bead) = 65 ml/min flow rate
(65 mL 1% SF_6/min = 0.65 mL SF_6/min x 1440 min/day x 3.53 x 10^{-5} ft^3/mL
= 0.0330 ft^3 SF_6/day)

Measured Tracer Gas Concentration (Negative Pressure)
= 160 ug/m3 = 26.8 ppbv = 26.8 x 10^{-9}

Measured Tracer Gas Concentration (Positive Pressure)
= 170 ug/m3 = 28.5 ppbv = 28.5 x 10^{-9}

Building Volume = Volume of demonstration building
(80 ft x 70 ft x 15 ft = 84,000 ft^3)

Example Calculation: Building Air Exchange Rate
Fresh Air Entry Rate = (0.0330 ft^3/day)/26.8 x 10^{-9} = 1,231,000 ft^3/day
ER = 1,231,000 ft^3/day / 84,000 ft^3 = 15 day^{-1}

Calculation Results: Building Air Exchange Rate

Test Building	Fresh Air Entry Rate (ft^3/day)	Air Exchange Rate (day^{-1})
SW Wing of Building 103: Negative Pressure	1,231,000	15
SW Wing of Building 103: Positive Pressure	1,158,000	14

GSI ENVIRONMENTAL

APPENDIX B: CALCULATION OF AIR EXCHANGE RATES

Proposed Tier 2 Screening Criteria and Tier 3 Field Procedures for Evaluation of Vapor Intrusion
ESTCP Project ER-0707

Appendix B.3 Parris Island Marine Base

$$\text{ER (day}^{-1}\text{)} = \frac{\text{Fresh Air Entry Rate (ft}^3\text{/day)}}{\text{Building Volume(ft}^3\text{)}}$$

$$\text{Fresh Air Entry Rate (ft}^3\text{/day)} = \frac{\text{Tracer Gas Release Rate (ft}^3\text{/day)}}{\text{Measured Tracer Gas Concentration (fraction)}}$$

Where:

ER = Building air exchange rate (day^{-1})
Fresh Air Entry Rate = Rate at which ambient air enters building (ft^3/day)
Tracer Gas Release Rate = Rate at which SF_6 tracer gas was released during test

100 ml/min rotameter reading (steel bead) = 80.3 ml/min flow rate
(80.3 mL 1% SF_6/min = 0.803 mL SF_6/min x 1440 min/day x 3.53 x 10^{-5} ft^3/mL
= 0.0408 ft^3 SF_6/day)

Measured Tracer Gas Concentration (Negative Pressure)
= 110 ug/m3 = 18.4 ppbv = 18.4 x 10^{-9}

Measured Tracer Gas Concentration (Positive Pressure)
= 120 ug/m3 = 20.1 ppbv = 20.1 x 10^{-9}

Building Volume = Volume of demonstration building
(65 ft x 65 ft x 15 ft = 63,400 ft^3)

Example Calculation: Building Air Exchange Rate

Fresh Air Entry Rate = (0.0408 ft^3/day)/18.4 x 10^{-9} = 2,217,000 ft^3/day
ER = 2,217,000 ft^3/day / 63,400 ft^3 = 35 day^{-1}

Calculation Results: Building Air Exchange Rate

Test Building	Fresh Air Entry Rate (ft^3/day)	Air Exchange Rate (day^{-1})
SW Wing of Building 103: Negative Pressure	2,217,000	35
SW Wing of Building 103: Positive Pressure	2,030,000	32

APPENDIX B: CALCULATION OF AIR EXCHANGE RATES

Proposed Tier 2 Screening Criteria and Tier 3 Field Procedures for Evaluation of Vapor Intrusion
ESTCP Project ER-0707

Appendix B.4 Hill AFB Round 1

$$\text{ER (day}^{-1}\text{)} = \frac{\text{Fresh Air Entry Rate (ft}^3\text{/day)}}{\text{Building Volume(ft}^3\text{)}}$$

$$\text{Fresh Air Entry Rate (ft}^3\text{/day)} = \frac{\text{Tracer Gas Release Rate (ft}^3\text{/day)}}{\text{Measured Tracer Gas Concentration (fraction)}}$$

Where:

ER = Building air exchange rate (day^{-1})
Fresh Air Entry Rate = Rate at which ambient air enters building (ft^3/day)
Tracer Gas Release Rate = Rate at which SF_6 tracer gas was released during test
100 ml/min rotameter reading (steel bead) = 1.56 ml/min flow rate
(1.56 mL 99.8% SF_6/min = 0.69 mL SF_6/min x 1440 min/day x 3.53 x 10^{-5} ft^3/mL
= 0.035 ft^3 SF_6/day)

Measured Tracer Gas Concentration (Baseline Pressure)
= 8,900 ug/m3 = 1,500 ppbv = 1500 x 10^{-9}

Measured Tracer Gas Concentration (Negative Pressure)
= 1,100 ug/m3 = 184 ppbv = 184 x 10^{-9}

Measured Tracer Gas Concentration (Positive Pressure)
= 1,600 ug/m3 = 268 ppbv = 268 x 10^{-9}

Building Volume = Volume of demonstration building
(22.83 ft x 36 ft x 8 ft) + (22.83 x 18 x 7.5) = 9,657 ft^3

Example Calculation: Building Air Exchange Rate (Baseline)
Fresh Air Entry Rate = (0.035 ft^3/day)/1500 x 10^{-9} = 23,000 ft^3/day
ER = 23,000 ft^3/day / 9,657 ft^3 = 2.4 day^{-1}

Calculation Results: Building Air Exchange Rate

Test Building	**Fresh Air Entry Rate (ft^3/day)**	**Air Exchange Rate (day^{-1})**
ASU House: Baseline	23,000	2.4
ASU House: Negative Pressure	190,000	19.7
ASU House: Positive Pressure	131,000	13.6

GSI ENVIRONMENTAL

APPENDIX B: CALCULATION OF AIR EXCHANGE RATES

Proposed Tier 2 Screening Criteria and Tier 3 Field Procedures for Evaluation of Vapor Intrusion
ESTCP Project ER-0707

Appendix B.5 Hill AFB Round 2

$$\text{ER (day}^{-1}) = \frac{\text{Fresh Air Entry Rate (ft}^3\text{/day)}}{\text{Building Volume(ft}^3)}$$

$$\text{Fresh Air Entry Rate (ft}^3\text{/day)} = \frac{\text{Tracer Gas Release Rate (ft}^3\text{/day)}}{\text{Measured Tracer Gas Concentration (fraction)}}$$

Where:

ER = Building air exchange rate (day^{-1})
Fresh Air Entry Rate = Rate at which ambient air enters building (ft^3/day)
Tracer Gas Release Rate = Rate at which SF_6 tracer gas was released during test
100 ml/min rotameter reading (steel bead) = 1.59 ml/min flow rate
(1.59 mL 99.8% SF_6/min = 0.70 mL SF_6/min x 1440 min/day x 3.53 x 10^{-5} ft^3/mL
= 0.036 ft^3 SF_6/day)

Measured Tracer Gas Concentration (Baseline Pressure)
= 5,200 ug/m3 = 871 ppbv = 871 x 10^{-9}

Measured Tracer Gas Concentration (Negative Pressure)
= 780 ug/m3 = 131 ppbv = 131 x 10^{-9}

Measured Tracer Gas Concentration (Positive Pressure)
= 870 ug/m3 = 146 ppbv = 146 x 10^{-9}

Building Volume = Volume of demonstration building
(22.83 ft x 36 ft x 8 ft) + (22.83 x 18 x 7.5) = 9,657 ft^3

Example Calculation: Building Air Exchange Rate (Baseline)
Fresh Air Entry Rate = (0.036 ft^3/day)/871 x 10^{-9} = 41,300 ft^3/day
ER = 41,300 ft^3/day / 9,657 ft^3 = 4.3 day^{-1}

Calculation Results: Building Air Exchange Rate

Test Building	**Fresh Air Entry Rate (ft^3/day)**	**Air Exchange Rate (day^{-1})**
ASU House: Baseline	41,300	4.3
ASU House: Negative Pressure	275,000	28.5
ASU House: Positive Pressure	247,000	25.6

APPENDIX B: CALCULATION OF AIR EXCHANGE RATES

Proposed Tier 2 Screening Criteria and Tier 3 Field Procedures for Evaluation of Vapor Intrusion
ESTCP Project ER-0707

Appendix B.6 Moffett Field NAS Round 1

$$\text{ER (day}^{-1}\text{)} = \frac{\text{Fresh Air Entry Rate (ft}^3\text{/day)}}{\text{Building Volume(ft}^3\text{)}}$$

$$\text{Fresh Air Entry Rate (ft}^3\text{/day)} = \frac{\text{Tracer Gas Release Rate (ft}^3\text{/day)}}{\text{Measured Tracer Gas Concentration (fraction)}}$$

Where:

ER = Building air exchange rate (day^{-1})
Fresh Air Entry Rate = Rate at which ambient air enters building (ft^3/day)
Tracer Gas Release Rate = Rate at which SF_6 tracer gas was released during test
100 ml/min rotameter reading (steel bead) = 1.56 ml/min flow rate
(1.56 mL 99.8% SF_6/min = 0.69 mL SF_6/min x 1440 min/day x 3.53 x 10^{-5} ft^3/mL
= 0.035 ft^3 SF_6/day)

Measured Tracer Gas Concentration (Baseline Pressure)
= 1,600 ug/m3 = 268 ppbv = 268 x 10^{-9}

Measured Tracer Gas Concentration (Negative Pressure)
= 260 ug/m3 = 44 ppbv = 44 x 10^{-9}

Measured Tracer Gas Concentration (Positive Pressure)
= 390 ug/m3 = 65 ppbv = 65 x 10^{-9}

Building Volume = Volume of demonstration building
(30.5 ft x 54.5 ft x 7.75 ft) = 12,882 ft^3

Example Calculation: Building Air Exchange Rate (Baseline)
Fresh Air Entry Rate = (0.035 ft^3/day)/268 x 10^{-9} = 131,000 ft^3/day
ER = 131,000 ft^3/day / 12,882 ft^3 = 10.2 day^{-1}

Calculation Results: Building Air Exchange Rate

Test Building	**Fresh Air Entry Rate (ft^3/day)**	**Air Exchange Rate (day^{-1})**
Building 107: Baseline	131,000	10.2
Building 107: Negative Pressure	795,000	61.7
Building 107: Positive Pressure	538,000	41.8

APPENDIX B: CALCULATION OF AIR EXCHANGE RATES

Proposed Tier 2 Screening Criteria and Tier 3 Field Procedures for Evaluation of Vapor Intrusion
ESTCP Project ER-0707

Appendix B.7 Moffett Field NAS Round 2

$$\text{ER (day}^{-1}\text{)} = \frac{\text{Fresh Air Entry Rate (ft}^3\text{/day)}}{\text{Building Volume(ft}^3\text{)}}$$

$$\text{Fresh Air Entry Rate (ft}^3\text{/day)} = \frac{\text{Tracer Gas Release Rate (ft}^3\text{/day)}}{\text{Measured Tracer Gas Concentration (fraction)}}$$

Where:

ER = Building air exchange rate (day^{-1})
Fresh Air Entry Rate = Rate at which ambient air enters building (ft^3/day)
Tracer Gas Release Rate = Rate at which SF_6 tracer gas was released during test
100 ml/min rotameter reading (steel bead) = 2.57 ml/min flow rate
(2.57 mL 99.8% SF_6/min = 1.14 mL SF_6/min x 1440 min/day x 3.53 x 10^{-5} ft^3/mL
= 0.058 ft^3 SF_6/day)

Measured Tracer Gas Concentration (Baseline Pressure)
= 3,300 ug/m3 = 553 ppbv = 553 x 10^{-9}

Measured Tracer Gas Concentration (Negative Pressure)
= 560 ug/m3 = 94 ppbv = 94 x 10^{-9}

Measured Tracer Gas Concentration (Positive Pressure)
= 530 ug/m3 = 89 ppbv = 89 x 10^{-9}

Building Volume = Volume of demonstration building
(30.5 ft x 54.5 ft x 7.75 ft) = 12,882 ft^3

Example Calculation: Building Air Exchange Rate (Baseline)
Fresh Air Entry Rate = (0.058 ft^3/day)/553 x 10^{-9} = 105,000 ft^3/day
ER = 105,000 ft^3/day / 12,882 ft^3 = 8.2 day^{-1}

Calculation Results: Building Air Exchange Rate

Test Building	Fresh Air Entry Rate (ft^3/day)	Air Exchange Rate (day^{-1})
Building 107: Baseline	105,000	8.2
Building 107: Negative Pressure	617,000	47.9
Building 107: Positive Pressure	652,000	50.6

Environmental Security Technology Certification Program
(ESTCP)

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Proposed Tier 2 Screening Criteria and Tier 3 Field Procedures for Evaluation of Vapor Intrusion
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Appendix C: Calculation of Soil Permeability

DETERMINATION OF SOIL AIR K

STEPS

1. Determine system Q vs p curve--plot curve Q on y axis, p on x axis.

2. Determine system + ground Q vs p curve--plot as in 1 above.

3. On the straightline portion of curve 2--pick two values of Q and subtract the pressure readings of the system curve from that of the system+ground curve. Connect these two points = ground Q vs p curve. Determine the slope of this curve.

4. To determine the soil air k (length^2) use the following formula based on steady state flow to a cylindrical source.

$$k = \frac{\text{slope} * (\text{viscosity of soil air}) * [\ln\{(L/D) + (1+(L/D)^2)^{.5}\}]}{2 * \text{pi} * L}$$

where k = permeability
L = length of cylindrical intake
D = diameter of cylindrical intake
pi = 3.1415

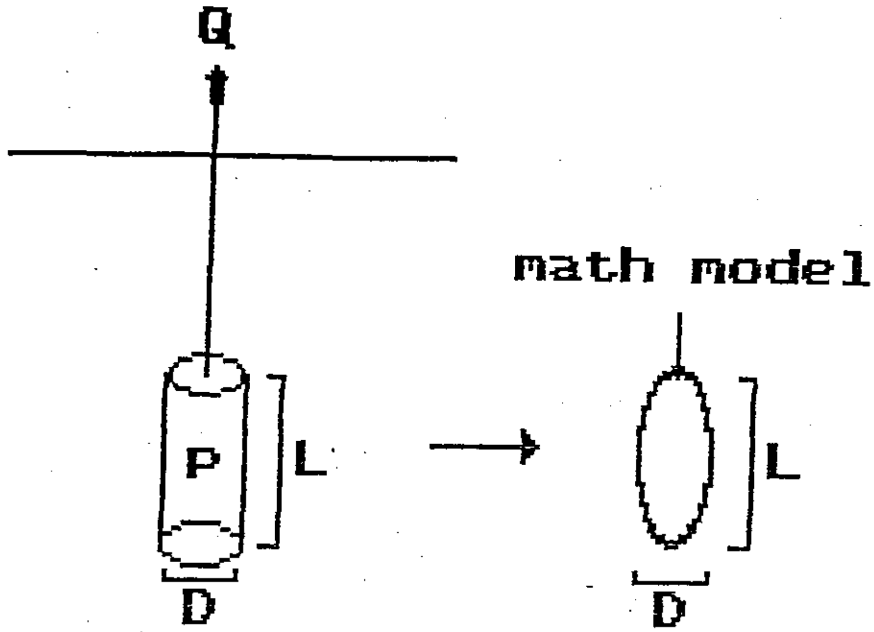
if Q (cc/min)
p (" of water)
L, D = cm
vis = poise [g/(cm.s)]

then k = cm^2 using

$$k = \frac{(1.07\times10^{-6}) * \text{slope} * \text{viscosity} * [\ln\{(L/D) + (1+(L/D)^2)^{.5}\}]}{L}$$

air viscosity (poise)	T°F	T°C
1.57×10^{-4}	0	-17.8
1.65×10^{-4}	10	-12.2
1.67×10^{-4}	20	- 6.67
1.71×10^{-4}	30	-1.11
1.73×10^{-4}	40	4.44
1.76×10^{-4}	50	10.0
1.79×10^{-4}	60	15.5
1.83×10^{-4}	70	21.2
1.84×10^{-4}	80	26.7
1.87×10^{-4}	90	32.2
1.89×10^{-4}	100	37.8

EQUATION FOR DETERMINING SOIL AIR K



-probe point is considered to be a cylindrical point imbedded in a homogeneous isotropic formation.

-air is considered to be incompressible--requires low p tests, steady flow.

-probe point is modeled as a elliptical source:
ref: Hvorslev 1951--taken from Dachler, R., Grundwasserstromung, Julius Springer, Wien, 1936.

modified interms of pressure--

$$Q = \frac{2*pi*L*k * p}{vis* [\ln\{(L/D) + (1+(L/D)^2)^{.5}\}]} + \text{gravitional head term}$$

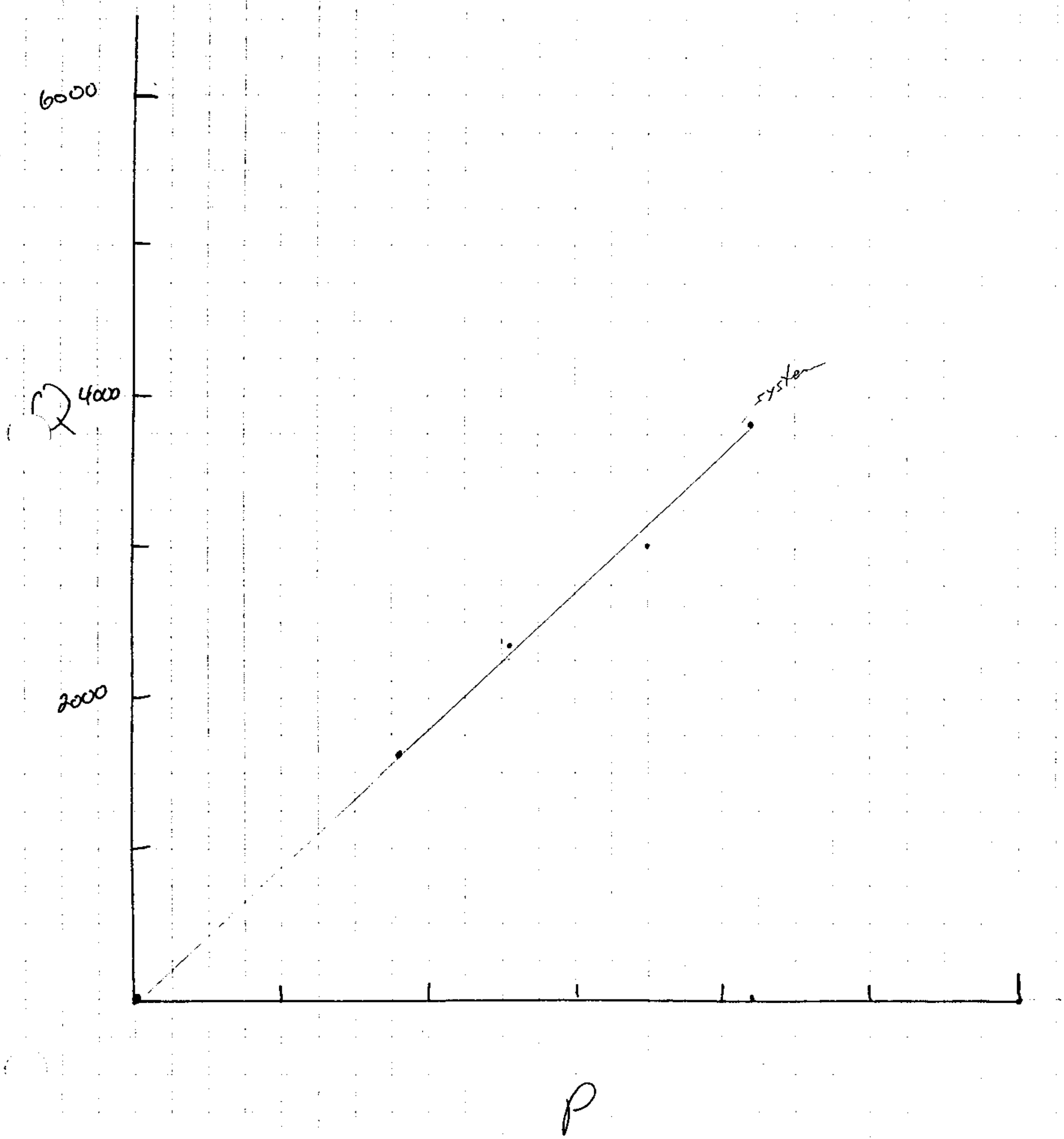
see a plot of Q vs p is straightline ---

Q = slope * p + intercept

solve slope--solve for k.

soil type	approx. k (cm^2) for dry soil
gravel	10^{-6} - 10^{-3}
clean sand	10^{-8} - 10^{-5}
silty sand	10^{-10} - 10^{-6}
clay	10^{-15} - 10^{-12}

K (cm/s) for water = k * 98,000


6000
Q 4000
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system
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Environmental Security Technology Certification Program
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Proposed Tier 2 Screening Criteria and Tier 3 Field Procedures for Evaluation of Vapor Intrusion
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Appendix D: Laboratory Reports

(Provided Electronically)

Environmental Security Technology Certification Program
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Proposed Tier 2 Screening Criteria and Tier 3 Field Procedures for Evaluation of Vapor Intrusion
ESTCP Project ER-200707

Appendix E: Data Quality Review Results

TABLE E.1
FIELD PRECISION ANALYSIS: FIELD DUPLICATE VARIABILITY
ESTCP: Vapor Intrusion Study

					1,1-Dichloroethene			Benzene		
					Sample	Duplicate	RPD	Sample	Duplicate	RPD
Matrix	Analytical Methods	Site	Sample Location	Sample Date	mg/L	mg/L	%	mg/L	mg/L	%
Groundwater	SW8260B	Former Pioneer Dry Cleaner	C1-PZ-1	1/9/2009	0.005	0.005	0%	<0.005	<0.005	nc
Groundwater	SW8260B	Former Pioneer Dry Cleaner	C2-PZ-1	1/9/2009	<0.005	<0.005	nc	<0.005	<0.005	nc
Groundwater	SW8260B	Travis AFB	C1-PZ-1	2/10/2009	<0.001	<0.001	nc	<0.0005	<0.0005	nc
Groundwater	SW8260B	Tinker AFB	C1-PZ-1	9/3/2009	<0.00013	<0.00013	nc	<0.00013	<0.00013	nc
Groundwater	SW8260B	Hill AFB	C1-PZ-1	8/25/2011	<0.00019	<0.00019	nc	<0.00008	<0.00008	nc
Groundwater	SW8260B	SPAWAR OTC Facility	C1-PZ-1	5/16/2011	<0.0002	<0.0002	nc	<0.0001	<0.0001	nc
Groundwater	SW8260B	SPAWAR OTC Facility	C2-PZ-1	5/16/2011	<0.0002	<0.0002	nc	<0.0001	<0.0001	nc
Groundwater	SW8260B	NIKE Battery Site PR-58	C1-PZ-1	8/1/2011	<0.00019	<0.00019	nc	<0.00008	<0.00008	nc
Groundwater	SW8260B	Industrial Site, SE Texas	C3-PZ-1	10/10/2011	1.81	1.92	6%	0.0324	0.0263	21%
Matrix	Analytical Methods	Site	Sample Location	Sample Date	ug/m3	ug/m3	%	ug/m3	ug/m3	%
Soil Gas	TO-15	Former Pioneer Dry Cleaner	C1-SG-2	1/9/2009	<79	<40	nc	94.5	118	22%
Soil Gas	TO-15, NIOSH 6602 (SF6)	Travis AFB	C2-SG-1	2/10/2009	<5	<5	nc	34	26	27%
Soil Gas	TO-15, NIOSH 6602 (SF6)	Tinker AFB	C3-SG-4	9/3/2009	<10	<10	nc	10	<10	0%
Soil Gas	GS (Radon)	Tinker AFB	SG-2-PP-2.5 FT	9/2/2009	-	-	-	-	-	-
Soil Gas	TO-15	Hill AFB	C1-SG-2	8/25/2011	<2.1	<2	nc	5.9	3.6	48%
Soil Gas	TO-15	SPAWAR OTC Facility	C1-SG-4	5/16/2011	<4	<4	nc	50	8.2	140%
Soil Gas	TO-15	SPAWAR OTC Facility	C2-SG-3	5/16/2011	<4	<4	nc	45	11	120%
Soil Gas	TO-15	NIKE Battery Site PR-58	C2-SG-2	8/2/2011	<0.39	<0.41	nc	9.4	6.2	41%
Soil Gas	TO-15	Industrial Site, SE Texas	C3-SG-4	10/11/2011	71000	76000	7%	<460	<460	nc
Matrix	Analytical Methods	Site	Sample Location	Sample Date	ug/m3	ug/m3	%	ug/m3	ug/m3	%
Sub-slab	TO-15, GS (Radon), 6602 (SF6)	Travis AFB	1	2/11/2009	<0.41	<0.4	nc	<0.41	<0.4	nc
Sub-slab	GS (Radon)	Travis AFB	1	2/12/2009	-	-	-	-	-	-
Sub-slab	TO-15, GS (Radon), 6602 (SF6)	NAS Jacksonville	2	3/17/2009	<34	<35	nc	<34	<35	nc
Sub-slab	GS (Radon)	NAS Jacksonville	2	3/18/2009	-	-	-	-	-	-
Sub-slab	TO-15, GS (Radon), 6602 (SF6)	Parris Island Marine Base	2	6/30/2009	<0.45	<0.49	nc	1	1.6	46%
Sub-slab	TO-15, GS (Radon)	Tinker AFB	2	9/1/2009	<0.44	<0.45	nc	1	0.77	26%
Sub-slab	TO-15 SIM, 6602 (SF6)	Hill AFB (ASU Research House)	Subslab-2	10/2/2010	0.098	0.11	12%	0.11	0.11	0%
Sub-slab	TO-15, GS (Radon), 6602 (SF6)	Hill AFB (ASU Research House)	Subslab-2	10/6/2010	310	350	12%	0.64	0.81	23%
Sub-slab	TO-15, 6602 (SF6)	Moffett Field NAS	Subslab-2	10/30/2010	<0.49	<0.45	nc	0.87	<0.45	64%
Sub-slab	TO-15, GS (Radon), 6602 (SF6)	Moffett Field NAS	Subslab-2	11/2/2010	<0.41	<0.4	nc	0.45	0.43	5%
Matrix	Analytical Methods	Site	Sample Location	Sample Date	ug/m3	ug/m3	%	ug/m3	ug/m3	%
Indoor Air	TO-15 SIM, 6602 (SF6)	Travis AFB	1	2/11/2009	<0.037	<0.037	nc	0.55	0.88	46%
Indoor Air	TO-15 SIM, 6602 (SF6)	NAS Jacksonville	2	3/17/2009	<0.039	<0.039	nc	0.6	0.58	3%
Indoor Air	TO-15 SIM, 6602 (SF6)	Parris Island Marine Base	3	6/30/2009	<0.047	<0.043	nc	0.43	0.42	2%
Indoor Air	TO-15 SIM	Tinker AFB	2	9/2/2009	<0.037	<0.04	nc	0.39	0.4	3%
Indoor Air	TO-15 SIM, GS (Radon), 6602 (SF6)	Hill AFB (ASU Research House)	Indoor-2	10/3/2010	13	11	17%	0.44	0.45	2%
Indoor Air	TO-15 SIM, GS (Radon), 6602 (SF6)	Hill AFB (ASU Research House)	Indoor-2	10/5/2010	0.13	0.13	0%	0.46	0.47	2%
Indoor Air	TO-15 SIM, GS (Radon), 6602 (SF6)	Moffett Field NAS	Indoor-2	11/1/2010	0.13	0.13	0%	1.1	1.2	9%
Matrix	Analytical Methods	Site	Sample Location	Sample Date	ug/m3	ug/m3	%	ug/m3	ug/m3	%
Ambient Air	TO-15 SIM, 6602 (SF6)	Hill AFB (ASU Research House)	Ambient-1	10/7/2010	<0.036	<0.042	nc	0.68	0.45	41%
Ambient Air	TO-15 SIM, GS (Radon), 6602 (SF6)	Moffett Field NAS	Ambient-1	10/31/2010	<0.041	<0.05	nc	0.3	0.5	50%

Notes:
1. Dash ("-") indicates that the compound was not analyzed in duplicate.
2. nc = Relative Percent Difference (RPD) not calculated.

TABLE E.1
FIELD PRECISION ANALYSIS: FIELD DUPLICATE VARIABILITY
ESTCP: Vapor Intrusion Study

					cis-1,2-Dichloroethene			Radon		
					Sample	Duplicate	RPD	Sample	Duplicate	RPD
Matrix	Analytical Methods	Site	Sample Location	Sample Date	mg/L	mg/L	%	mg/L	mg/L	%
Groundwater	SW8260B	Former Pioneer Dry Cleaner	C1-PZ-1	1/9/2009	0.97	1	3%	-	-	-
Groundwater	SW8260B	Former Pioneer Dry Cleaner	C2-PZ-1	1/9/2009	<0.005	<0.005	nc	-	-	-
Groundwater	SW8260B	Travis AFB	C1-PZ-1	2/10/2009	<0.001	<0.001	nc	-	-	-
Groundwater	SW8260B	Tinker AFB	C1-PZ-1	9/3/2009	0.0048	0.0048	0%	-	-	-
Groundwater	SW8260B	Hill AFB	C1-PZ-1	8/25/2011	<0.00006	<0.00006	nc	-	-	-
Groundwater	SW8260B	SPAWAR OTC Facility	C1-PZ-1	5/16/2011	3.7	3.4	9%	-	-	-
Groundwater	SW8260B	SPAWAR OTC Facility	C2-PZ-1	5/16/2011	9.4	8.3	12%	-	-	-
Groundwater	SW8260B	NIKE Battery Site PR-58	C1-PZ-1	8/1/2011	0.029	0.023	23%	-	-	-
Groundwater	SW8260B	Industrial Site, SE Texas	C3-PZ-1	10/10/2011	1.9	1.92	1%	-	-	-
Matrix	Analytical Methods	Site	Sample Location	Sample Date	ug/m3	ug/m3	%	pCi/L	pCi/L	%
Soil Gas	TO-15	Former Pioneer Dry Cleaner	C1-SG-2	1/9/2009	<79	<40	nc	-	-	-
Soil Gas	TO-15, NIOSH 6602 (SF6)	Travis AFB	C2-SG-1	2/10/2009	<5	<5	nc	-	-	-
Soil Gas	TO-15, NIOSH 6602 (SF6)	Tinker AFB	C3-SG-4	9/3/2009	<10	<10	nc	-	-	-
Soil Gas	GS (Radon)	Tinker AFB	SG-2-PP-2.5 FT	9/2/2009	-	-	-	7.8	8.6	11%
Soil Gas	TO-15	Hill AFB	C1-SG-2	8/25/2011	<2.1	<2	nc	-	-	-
Soil Gas	TO-15	SPAWAR OTC Facility	C1-SG-4	5/16/2011	<4	<4	nc	-	-	-
Soil Gas	TO-15	SPAWAR OTC Facility	C2-SG-3	5/16/2011	<4	<4	nc	-	-	-
Soil Gas	TO-15	NIKE Battery Site PR-58	C2-SG-2	8/2/2011	<0.39	<0.41	nc	-	-	-
Soil Gas	TO-15	Industrial Site, SE Texas	C3-SG-4	10/11/2011	17000	17000	0%	-	-	-
Matrix	Analytical Methods	Site	Sample Location	Sample Date	ug/m3	ug/m3	%	pCi/L	pCi/L	%
Sub-slab	TO-15, GS (Radon), 6602 (SF6)	Travis AFB	1	2/11/2009	<0.41	<0.4	nc	739	736	0%
Sub-slab	GS (Radon)	Travis AFB	1	2/12/2009	-	-	-	835	815	2%
Sub-slab	TO-15, GS (Radon), 6602 (SF6)	NAS Jacksonville	2	3/17/2009	4400	3900	12%	122	127	4%
Sub-slab	GS (Radon)	NAS Jacksonville	2	3/18/2009	-	-	-	95	99	4%
Sub-slab	TO-15, GS (Radon), 6602 (SF6)	Parris Island Marine Base	2	6/30/2009	<0.45	<0.49	nc	2681	2752	3%
Sub-slab	TO-15, GS (Radon)	Tinker AFB	2	9/1/2009	<0.44	<0.45	nc	70	71	2%
Sub-slab	TO-15 SIM, 6602 (SF6)	Hill AFB (ASU Research House)	Subslab-2	10/2/2010	<0.032	<0.032	nc	-	-	-
Sub-slab	TO-15, GS (Radon), 6602 (SF6)	Hill AFB (ASU Research House)	Subslab-2	10/6/2010	48	51	6%	106	99	6%
Sub-slab	TO-15, 6602 (SF6)	Moffett Field NAS	Subslab-2	10/30/2010	<0.49	<0.45	nc	-	-	-
Sub-slab	TO-15, GS (Radon), 6602 (SF6)	Moffett Field NAS	Subslab-2	11/2/2010	<0.41	<0.4	nc	271	281	4%
Matrix	Analytical Methods	Site	Sample Location	Sample Date	ug/m3	ug/m3	%	pCi/L	pCi/L	%
Indoor Air	TO-15 SIM, 6602 (SF6)	Travis AFB	1	2/11/2009	0.047	0.041	14%	-	-	-
Indoor Air	TO-15 SIM, 6602 (SF6)	NAS Jacksonville	2	3/17/2009	1	1.1	10%	-	-	-
Indoor Air	TO-15 SIM, 6602 (SF6)	Parris Island Marine Base	3	6/30/2009	1.8	2.5	33%	-	-	-
Indoor Air	TO-15 SIM	Tinker AFB	2	9/2/2009	<0.037	<0.04	nc	-	-	-
Indoor Air	TO-15 SIM, GS (Radon), 6602 (SF6)	Hill AFB (ASU Research House)	Indoor-2	10/3/2010	2	1.7	16%	3	4.5	40%
Indoor Air	TO-15 SIM, GS (Radon), 6602 (SF6)	Hill AFB (ASU Research House)	Indoor-2	10/5/2010	0.058	0.064	10%	0.33	0.34	4%
Indoor Air	TO-15 SIM, GS (Radon), 6602 (SF6)	Moffett Field NAS	Indoor-2	11/1/2010	2	2	0%	0.92	1.2	25%
Matrix	Analytical Methods	Site	Sample Location	Sample Date	ug/m3	ug/m3	%	pCi/L	pCi/L	%
Ambient Air	TO-15 SIM, 6602 (SF6)	Hill AFB (ASU Research House)	Ambient-1	10/7/2010	<0.036	<0.042	nc	-	-	-
Ambient Air	TO-15 SIM, GS (Radon), 6602 (SF6)	Moffett Field NAS	Ambient-1	10/31/2010	<0.041	<0.05	nc	0.035	0.069	65%

Notes:
1. Dash ("-") indicates that the compound was not analyzed in duplicate.
2. nc = Relative Percent Difference (RPD) not calculated.

TABLE E.1
FIELD PRECISION ANALYSIS: FIELD DUPLICATE VARIABILITY
ESTCP: Vapor Intrusion Study

					Sulfur Hexafluoride			Tetrachloroethene		
					Sample	Duplicate	RPD	Sample	Duplicate	RPD
Matrix	Analytical Methods	Site	Sample Location	Sample Date	mg/L	mg/L	%	mg/L	mg/L	%
Groundwater	SW8260B	Former Pioneer Dry Cleaner	C1-PZ-1	1/9/2009	-	-	-	15	17	13%
Groundwater	SW8260B	Former Pioneer Dry Cleaner	C2-PZ-1	1/9/2009	-	-	-	<0.005	<0.005	nc
Groundwater	SW8260B	Travis AFB	C1-PZ-1	2/10/2009	-	-	-	<0.001	<0.001	nc
Groundwater	SW8260B	Tinker AFB	C1-PZ-1	9/3/2009	-	-	-	<0.00008	<0.00008	nc
Groundwater	SW8260B	Hill AFB	C1-PZ-1	8/25/2011	-	-	-	<0.00013	<0.00013	nc
Groundwater	SW8260B	SPAWAR OTC Facility	C1-PZ-1	5/16/2011	-	-	-	<0.0002	<0.0002	nc
Groundwater	SW8260B	SPAWAR OTC Facility	C2-PZ-1	5/16/2011	-	-	-	<0.0002	<0.0002	nc
Groundwater	SW8260B	NIKE Battery Site PR-58	C1-PZ-1	8/1/2011	-	-	-	0.0029	0.0033	13%
Groundwater	SW8260B	Industrial Site, SE Texas	C3-PZ-1	10/10/2011	-	-	-	0.284	0.34	18%
Matrix	Analytical Methods	Site	Sample Location	Sample Date	ug/m3	ug/m3	%	ug/m3	ug/m3	%
Soil Gas	TO-15	Former Pioneer Dry Cleaner	C1-SG-2	1/9/2009	-	-	-	<136	<67.8	nc
Soil Gas	TO-15, NIOSH 6602 (SF6)	Travis AFB	C2-SG-1	2/10/2009	<6	<6	nc	<5	<5	nc
Soil Gas	TO-15, NIOSH 6602 (SF6)	Tinker AFB	C3-SG-4	9/3/2009	190	100	62%	<10	<10	nc
Soil Gas	GS (Radon)	Tinker AFB	SG-2-PP-2.5 FT	9/2/2009	-	-	-	-	-	-
Soil Gas	TO-15	Hill AFB	C1-SG-2	8/25/2011	-	-	-	<2.1	<2	nc
Soil Gas	TO-15	SPAWAR OTC Facility	C1-SG-4	5/16/2011	-	-	-	27	17	45%
Soil Gas	TO-15	SPAWAR OTC Facility	C2-SG-3	5/16/2011	-	-	-	<6.9	<6.9	nc
Soil Gas	TO-15	NIKE Battery Site PR-58	C2-SG-2	8/2/2011	-	-	-	<0.39	0.92	81%
Soil Gas	TO-15	Industrial Site, SE Texas	C3-SG-4	10/11/2011	-	-	-	14000	13000	7%
Matrix	Analytical Methods	Site	Sample Location	Sample Date	ug/m3	ug/m3	%	ug/m3	ug/m3	%
Sub-slab	TO-15, GS (Radon), 6602 (SF6)	Travis AFB	1	2/11/2009	<9.7	<9.6	nc	<0.41	<0.4	nc
Sub-slab	GS (Radon)	Travis AFB	1	2/12/2009	-	-	-	-	-	-
Sub-slab	TO-15, GS (Radon), 6602 (SF6)	NAS Jacksonville	2	3/17/2009	17	16	6%	21000	22000	5%
Sub-slab	GS (Radon)	NAS Jacksonville	2	3/18/2009	-	-	-	-	-	-
Sub-slab	TO-15, GS (Radon), 6602 (SF6)	Parris Island Marine Base	2	6/30/2009	<6.6	10	41%	240	120	67%
Sub-slab	TO-15, GS (Radon)	Tinker AFB	2	9/1/2009	-	-	-	31	29	7%
Sub-slab	TO-15 SIM, 6602 (SF6)	Hill AFB (ASU Research House)	Subslab-2	10/2/2010	2400	2600	8%	0.55	0.53	4%
Sub-slab	TO-15, GS (Radon), 6602 (SF6)	Hill AFB (ASU Research House)	Subslab-2	10/6/2010	14	18	25%	92	110	18%
Sub-slab	TO-15, 6602 (SF6)	Moffett Field NAS	Subslab-2	10/30/2010	24	22	9%	0.85	0.63	30%
Sub-slab	TO-15, GS (Radon), 6602 (SF6)	Moffett Field NAS	Subslab-2	11/2/2010	86	80	7%	0.55	3.2	140%
Matrix	Analytical Methods	Site	Sample Location	Sample Date	ug/m3	ug/m3	%	ug/m3	ug/m3	%
Indoor Air	TO-15 SIM, 6602 (SF6)	Travis AFB	1	2/11/2009	110	110	0%	0.066	0.069	4%
Indoor Air	TO-15 SIM, 6602 (SF6)	NAS Jacksonville	2	3/17/2009	66	65	2%	1.9	1.9	0%
Indoor Air	TO-15 SIM, 6602 (SF6)	Parris Island Marine Base	3	6/30/2009	110	160	37%	35	22	46%
Indoor Air	TO-15 SIM	Tinker AFB	2	9/2/2009	-	-	-	0.51	0.22	79%
Indoor Air	TO-15 SIM, GS (Radon), 6602 (SF6)	Hill AFB (ASU Research House)	Indoor-2	10/3/2010	520	630	19%	4.1	3.6	13%
Indoor Air	TO-15 SIM, GS (Radon), 6602 (SF6)	Hill AFB (ASU Research House)	Indoor-2	10/5/2010	5100	4900	4%	0.17	0.19	11%
Indoor Air	TO-15 SIM, GS (Radon), 6602 (SF6)	Moffett Field NAS	Indoor-2	11/1/2010	3400	3200	6%	2.9	2.9	0%
Matrix	Analytical Methods	Site	Sample Location	Sample Date	ug/m3	ug/m3	%	ug/m3	ug/m3	%
Ambient Air	TO-15 SIM, 6602 (SF6)	Hill AFB (ASU Research House)	Ambient-1	10/7/2010	12	<10	18%	0.089	0.11	21%
Ambient Air	TO-15 SIM, GS (Radon), 6602 (SF6)	Moffett Field NAS	Ambient-1	10/31/2010	<9.7	<12	nc	0.047	0.074	45%

Notes:
1. Dash ("-") indicates that the compound was not analyzed in duplicate.
2. nc = Relative Percent Difference (RPD) not calculated.

TABLE E.1
FIELD PRECISION ANALYSIS: FIELD DUPLICATE VARIABILITY
ESTCP: Vapor Intrusion Study

					Toluene			Trichloroethene		
					Sample	Duplicate	RPD	Sample	Duplicate	RPD
Matrix	Analytical Methods	Site	Sample Location	Sample Date	mg/L	mg/L	%	mg/L	mg/L	%
Groundwater	SW8260B	Former Pioneer Dry Cleaner	C1-PZ-1	1/9/2009	<0.005	<0.005	nc	0.93	1	7%
Groundwater	SW8260B	Former Pioneer Dry Cleaner	C2-PZ-1	1/9/2009	<0.005	<0.005	nc	<0.005	<0.005	nc
Groundwater	SW8260B	Travis AFB	C1-PZ-1	2/10/2009	<0.001	<0.001	nc	0.0021	0.0019	10%
Groundwater	SW8260B	Tinker AFB	C1-PZ-1	9/3/2009	<0.00014	<0.00014	nc	<0.00013	<0.003 B	nc
Groundwater	SW8260B	Hill AFB	C1-PZ-1	8/25/2011	<0.00015	<0.00015	nc	0.005	0.0056	11%
Groundwater	SW8260B	SPAWAR OTC Facility	C1-PZ-1	5/16/2011	<0.0001	<0.0001	nc	<0.0002	<0.0002	nc
Groundwater	SW8260B	SPAWAR OTC Facility	C2-PZ-1	5/16/2011	<0.0001	<0.0001	nc	<0.0002	<0.0002	nc
Groundwater	SW8260B	NIKE Battery Site PR-58	C1-PZ-1	8/1/2011	<0.00015	<0.00015	nc	0.13	0.14	7%
Groundwater	SW8260B	Industrial Site, SE Texas	C3-PZ-1	10/10/2011	0.000232J	0.000229J	1%	0.0775	0.0813	5%
Matrix	Analytical Methods	Site	Sample Location	Sample Date	ug/m3	ug/m3	%	ug/m3	ug/m3	%
Soil Gas	TO-15	Former Pioneer Dry Cleaner	C1-SG-2	1/9/2009	<75.3	60.2	22%	<110	<54	nc
Soil Gas	TO-15, NIOSH 6602 (SF6)	Travis AFB	C2-SG-1	2/10/2009	14	16	13%	30	24	22%
Soil Gas	TO-15, NIOSH 6602 (SF6)	Tinker AFB	C3-SG-4	9/3/2009	15	15	0%	<10	<10	nc
Soil Gas	GS (Radon)	Tinker AFB	SG-2-PP-2.5 FT	9/2/2009	-	-	-	-	-	-
Soil Gas	TO-15	Hill AFB	C1-SG-2	8/25/2011	15	10	40%	7.3	7.6	4%
Soil Gas	TO-15	SPAWAR OTC Facility	C1-SG-4	5/16/2011	4.1	<3.8	8%	<5.5	<5.5	nc
Soil Gas	TO-15	SPAWAR OTC Facility	C2-SG-3	5/16/2011	13	8.2	45%	<5.5	<5.5	nc
Soil Gas	TO-15	NIKE Battery Site PR-58	C2-SG-2	8/2/2011	5	26	140%	0.57	0.57	0%
Soil Gas	TO-15	Industrial Site, SE Texas	C3-SG-4	10/11/2011	<460	<460	nc	2100	2100	0%
Matrix	Analytical Methods	Site	Sample Location	Sample Date	ug/m3	ug/m3	%	ug/m3	ug/m3	%
Sub-slab	TO-15, GS (Radon), 6602 (SF6)	Travis AFB	1	2/11/2009	<2	<2	nc	<0.41	<0.4	nc
Sub-slab	GS (Radon)	Travis AFB	1	2/12/2009	-	-	-	-	-	-
Sub-slab	TO-15, GS (Radon), 6602 (SF6)	NAS Jacksonville	2	3/17/2009	<170	<170	nc	2900	2800	4%
Sub-slab	GS (Radon)	NAS Jacksonville	2	3/18/2009	-	-	-	-	-	-
Sub-slab	TO-15, GS (Radon), 6602 (SF6)	Parris Island Marine Base	2	6/30/2009	<2.3	18	150%	0.95	<0.49	64%
Sub-slab	TO-15, GS (Radon)	Tinker AFB	2	9/1/2009	12	7.8	42%	1.9	1.7	11%
Sub-slab	TO-15 SIM, 6602 (SF6)	Hill AFB (ASU Research House)	Subslab-2	10/2/2010	0.36	0.35	3%	12	12	0%
Sub-slab	TO-15, GS (Radon), 6602 (SF6)	Hill AFB (ASU Research House)	Subslab-2	10/6/2010	<2	2.5	22%	390	420 D	7%
Sub-slab	TO-15, 6602 (SF6)	Moffett Field NAS	Subslab-2	10/30/2010	<2.5	<2.3	nc	0.5	0.59	17%
Sub-slab	TO-15, GS (Radon), 6602 (SF6)	Moffett Field NAS	Subslab-2	11/2/2010	<2.1	<2	nc	1	1.3	26%
Matrix	Analytical Methods	Site	Sample Location	Sample Date	ug/m3	ug/m3	%	ug/m3	ug/m3	%
Indoor Air	TO-15 SIM, 6602 (SF6)	Travis AFB	1	2/11/2009	1.2	1.9	45%	0.25	0.24	4%
Indoor Air	TO-15 SIM, 6602 (SF6)	NAS Jacksonville	2	3/17/2009	3.1	3.2	3%	0.45	0.43	5%
Indoor Air	TO-15 SIM, 6602 (SF6)	Parris Island Marine Base	3	6/30/2009	13	13	0%	0.54	0.73	30%
Indoor Air	TO-15 SIM	Tinker AFB	2	9/2/2009	0.62	0.71	14%	<0.037	<0.04	nc
Indoor Air	TO-15 SIM, GS (Radon), 6602 (SF6)	Hill AFB (ASU Research House)	Indoor-2	10/3/2010	1.3	1.1	17%	19	17	11%
Indoor Air	TO-15 SIM, GS (Radon), 6602 (SF6)	Hill AFB (ASU Research House)	Indoor-2	10/5/2010	2.2	4.3	65%	22	23	4%
Indoor Air	TO-15 SIM, GS (Radon), 6602 (SF6)	Moffett Field NAS	Indoor-2	11/1/2010	4	4.6	14%	5	5.1	2%
Matrix	Analytical Methods	Site	Sample Location	Sample Date	ug/m3	ug/m3	%	ug/m3	ug/m3	%
Ambient Air	TO-15 SIM, 6602 (SF6)	Hill AFB (ASU Research House)	Ambient-1	10/7/2010	2.1	1.5	33%	0.045	0.084	60%
Ambient Air	TO-15 SIM, GS (Radon), 6602 (SF6)	Moffett Field NAS	Ambient-1	10/31/2010	1.1	2.1	63%	<0.041	0.056	31%

Notes:
1. Dash ("-") indicates that the compound was not analyzed in duplicate.
2. nc = Relative Percent Difference (RPD) not calculated.

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TABLE E.1
FIELD PRECISION ANALYSIS: FIELD DUPLICATE VARIABILITY
ESTCP: Vapor Intrusion Study

					Vinyl Chloride		
					Sample	Duplicate	RPD
Matrix	Analytical Methods	Site	Sample Location	Sample Date	mg/L	mg/L	%
Groundwater	SW8260B	Former Pioneer Dry Cleaner	C1-PZ-1	1/9/2009	0.043	0.041	5%
Groundwater	SW8260B	Former Pioneer Dry Cleaner	C2-PZ-1	1/9/2009	<0.01	<0.01	nc
Groundwater	SW8260B	Travis AFB	C1-PZ-1	2/10/2009	<0.0005	<0.0005	nc
Groundwater	SW8260B	Tinker AFB	C1-PZ-1	9/3/2009	<0.00013	0.00091J	150%
Groundwater	SW8260B	Hill AFB	C1-PZ-1	8/25/2011	<0.00011	<0.00011	nc
Groundwater	SW8260B	SPAWAR OTC Facility	C1-PZ-1	5/16/2011	47	46	2%
Groundwater	SW8260B	SPAWAR OTC Facility	C2-PZ-1	5/16/2011	420	410	2%
Groundwater	SW8260B	NIKE Battery Site PR-58	C1-PZ-1	8/1/2011	<0.00011	<0.00011	nc
Groundwater	SW8260B	Industrial Site, SE Texas	C3-PZ-1	10/10/2011	0.762	0.78	2%
Matrix	Analytical Methods	Site	Sample Location	Sample Date	ug/m3	ug/m3	%
Soil Gas	TO-15	Former Pioneer Dry Cleaner	C1-SG-2	1/9/2009	<51	<26	nc
Soil Gas	TO-15, NIOSH 6602 (SF6)	Travis AFB	C2-SG-1	2/10/2009	<5	<5	nc
Soil Gas	TO-15, NIOSH 6602 (SF6)	Tinker AFB	C3-SG-4	9/3/2009	<10	<10	nc
Soil Gas	GS (Radon)	Tinker AFB	SG-2-PP-2.5 FT	9/2/2009	-	-	-
Soil Gas	TO-15	Hill AFB	C1-SG-2	8/25/2011	<2.1	<2	nc
Soil Gas	TO-15	SPAWAR OTC Facility	C1-SG-4	5/16/2011	<2.6	<2.6	nc
Soil Gas	TO-15	SPAWAR OTC Facility	C2-SG-3	5/16/2011	11	3.7	99%
Soil Gas	TO-15	NIKE Battery Site PR-58	C2-SG-2	8/2/2011	<0.39	<0.41	nc
Soil Gas	TO-15	Industrial Site, SE Texas	C3-SG-4	10/11/2011	850	890	5%
Matrix	Analytical Methods	Site	Sample Location	Sample Date	ug/m3	ug/m3	%
Sub-slab	TO-15, GS (Radon), 6602 (SF6)	Travis AFB	1	2/11/2009	<0.41	<0.4	nc
Sub-slab	GS (Radon)	Travis AFB	1	2/12/2009	-	-	-
Sub-slab	TO-15, GS (Radon), 6602 (SF6)	NAS Jacksonville	2	3/17/2009	<34	<35	nc
Sub-slab	GS (Radon)	NAS Jacksonville	2	3/18/2009	-	-	-
Sub-slab	TO-15, GS (Radon), 6602 (SF6)	Parris Island Marine Base	2	6/30/2009	<0.45	<0.49	nc
Sub-slab	TO-15, GS (Radon)	Tinker AFB	2	9/1/2009	<0.44	<0.45	nc
Sub-slab	TO-15 SIM, 6602 (SF6)	Hill AFB (ASU Research House)	Subslab-2	10/2/2010	<0.032	<0.032	nc
Sub-slab	TO-15, GS (Radon), 6602 (SF6)	Hill AFB (ASU Research House)	Subslab-2	10/6/2010	0.68	0.76	11%
Sub-slab	TO-15, 6602 (SF6)	Moffett Field NAS	Subslab-2	10/30/2010	<0.49	<0.45	nc
Sub-slab	TO-15, GS (Radon), 6602 (SF6)	Moffett Field NAS	Subslab-2	11/2/2010	<0.41	<0.4	nc
Matrix	Analytical Methods	Site	Sample Location	Sample Date	ug/m3	ug/m3	%
Indoor Air	TO-15 SIM, 6602 (SF6)	Travis AFB	1	2/11/2009	<0.037	<0.037	nc
Indoor Air	TO-15 SIM, 6602 (SF6)	NAS Jacksonville	2	3/17/2009	<0.039	<0.039	nc
Indoor Air	TO-15 SIM, 6602 (SF6)	Parris Island Marine Base	3	6/30/2009	0.09	0.12	29%
Indoor Air	TO-15 SIM	Tinker AFB	2	9/2/2009	<0.037	<0.04	nc
Indoor Air	TO-15 SIM, GS (Radon), 6602 (SF6)	Hill AFB (ASU Research House)	Indoor-2	10/3/2010	0.1	0.082	20%
Indoor Air	TO-15 SIM, GS (Radon), 6602 (SF6)	Hill AFB (ASU Research House)	Indoor-2	10/5/2010	<0.04	<0.047	nc
Indoor Air	TO-15 SIM, GS (Radon), 6602 (SF6)	Moffett Field NAS	Indoor-2	11/1/2010	<0.037	<0.032	nc
Matrix	Analytical Methods	Site	Sample Location	Sample Date	ug/m3	ug/m3	%
Ambient Air	TO-15 SIM, 6602 (SF6)	Hill AFB (ASU Research House)	Ambient-1	10/7/2010	<0.036	<0.042	nc
Ambient Air	TO-15 SIM, GS (Radon), 6602 (SF6)	Moffett Field NAS	Ambient-1	10/31/2010	<0.041	<0.05	nc

Notes:
1. Dash ("-") indicates that the compound was not analyzed in duplicate.
2. nc = Relative Percent Difference (RPD) not calculated.

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TABLE E.2
FIELD ACCURACY ANALYSIS: TRIP BLANK AND FIELD BLANK SAMPLES
ESTCP: Vapor Intrusion Study

SITE:	Fmr. Pioneer Cleaners		Travis AFB		Tinker AFB	
SAMPLE ID:	**09010372-16**	**09010372-15**	**09-02-1493-11-B**	**09-02-1493-10-B**	**600-14806-13**	**600-14806-11**
SAMPLE LOCATION:	Trip Blank	Field Blank	Trip Blank	Field Blank	Trip Blank	Field Blank
SCREEN INTERVAL (ft BGS):	NA	NA	NA	NA	NA	NA
SAMPLE TYPE:	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater	Groundwater
SAMPLE DATE:	NA	1/9/2009	NA	2/10/2009	NA	9/3/2009
COMPOUND	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Compounds of Interest						
1,1-Dichloroethene	<0.005	<0.005	<0.001	<0.001	<0.00013	<0.00013
Benzene	<0.005	<0.005	<0.0005	<0.0005	<0.00013	<0.00013
Dichloroethene cis- 1,2-	<0.005	<0.005	<0.001	<0.001	<0.00016	<0.00016
Tetrachloroethene	<0.005	<0.005	<0.001	<0.001	<0.00008	<0.00008
Toluene	<0.005	<0.005	<0.001	<0.001	<0.00014	<0.00014
Trichloroethene	<0.005	<0.005	<0.001	<0.001	<0.003 B	**0.0006 J,H**
Vinyl chloride	<0.01	<0.01	<0.0005	<0.0005	<0.00013	<0.00013

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TABLE E.2
FIELD ACCURACY ANALYSIS: TRIP BLANK AND FIELD BLANK SAMPLES
ESTCP: Vapor Intrusion Study

SITE:	Hill AFB	SPAWAR OTC	Nike	Industrial Site, SE Texas
SAMPLE ID:	**600-42630-11**	**E105055-12**	**600-41712-10**	**600-41712-10**
SAMPLE LOCATION:	Trip Blank	Trip Blank	Trip Blank	Trip Blank
SCREEN INTERVAL (ft BGS):	NA	NA	NA	NA
SAMPLE TYPE:	Groundwater	Groundwater	Groundwater	Groundwater
SAMPLE DATE:	NA	NA	NA	NA
COMPOUND	mg/L	mg/L	mg/L	mg/L
Compounds of Interest				
1,1-Dichloroethene	<0.00019	<0.001	<0.00019	<0.00019
Benzene	<0.00008	<0.0005	<0.00008	<0.00008
Dichloroethene cis- 1,2-	<0.00006	<0.001	<0.00006	<0.00006
Tetrachloroethene	<0.00013	<0.001	<0.00013	<0.00013
Toluene	<0.00015	<0.0005	<0.00015	<0.00015
Trichloroethene	<0.00018	<0.001	<0.00018	<0.00018
Vinyl chloride	<0.00011	<0.001	<0.00011	<0.00011

Notes:
1. Groundwater samples collected at the Former Pioneer Cleaners Site were analyzed by SPL, Inc., Houston, Texas by Method 8260B.
2. Groundwater samples collected at Travis Air Force Base were analyzed by Calcience Environmental Laboratories, Inc., Garden Grove, California by Method 8260B.
3. Groundwater samples collected at Tinker Air Force Base, Hill Air Force Base, NIKE, and Industrial Site were analyzed by TestAmerica Laboratories, Inc., in Houston, Texas by Method 8260B.
4. Groundwater samples collected at SPAWAR OTC were analyzed by H&P Mobile Geochemistry Inc. in Carlsbad, California by Method 8260B.
5. Detected analytes are presented in bold type.
6. < = not detected at detection limit;. J = analyte is an estimated value; H = bias in sample result likely to be high.

Environmental Security Technology Certification Program
(ESTCP)

FINAL REPORT

Proposed Tier 2 Screening Criteria and Tier 3 Field Procedures for Evaluation of Vapor Intrusion
ESTCP Project ER-200707

Appendix F: Results of ANOVA Analysis

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APPENDIX F.1: Results of Statistical Analyses for Tier 2 Demonstration
Final Report, ER-0707

Linear Regression Log Native Hydraulic Conductivity vs Log Attenuation Factor (Clusters)

Regression Statistics

R	0.31254
R Square	0.09768
Adjusted R Sc	0.02827
Standard Errc	1.31381
Total Number	15

A =- 2.4115 - 0.1472 * B

ANOVA

	d.f.	*SS*	*MS*	*F*	*p-level*
Regression	1.	2.42911	2.42911	1.40729	0.25674
Residual	13.	22.43909	1.72608		
Total	14.	24.86819			

	Coefficients	*Standard Error*	*LCL*	*UCL*	*t Stat*	*p-level*	*H0 (2%) rejected?*
Intercept	-2.41148	0.36091	-3.36799	-1.45497	-6.68176	0.00002	*Yes*
B	-0.14721	0.12409	-0.47609	0.18167	-1.18629	0.25674	*No*

T (2%) 2.65031
LCL - Lower value of a reliable interval (LCL)
UCL - Upper value of a reliable interval (UCL)

Residuals

Observation	*Predicted Y*	*Residual*	*ındard Residuals*
1	-2.17641	-2.89418	-2.28605
2	-2.18009	0.64249	0.50749
3	-2.08853	0.25756	0.20344
4	-2.15639	-0.30402	-0.24014
5	-2.07819	-2.52387	-1.99356
6	-2.13736	-0.43734	-0.34544
7	-2.77625	1.00747	0.79578
8	-2.83137	-0.16863	-0.1332
9	-2.85243	-0.70041	-0.55324
10	-2.52226	0.9202	0.72685
11	-2.63991	1.35591	1.07101
12	-2.5579	0.3331	0.26311
13	-1.71977	0.31425	0.24822
14	-1.64111	0.8905	0.70339
15	-1.62185	1.30695	1.03234

APPENDIX F.1: Results of Statistical Analyses for Tier 2 Demonstration
Final Report, ER-0707

Linear Regression - Log Soil Permeability vs Log Atteuation Factor (Clusters)

Regression Statistics

R	0.69725
R Square	0.48616
Adjusted R Sc	0.4519
Standard Erro	1.11906
Total Number	17

A = 5.7347 + 0.9724 * B

ANOVA

	d.f.	*SS*	*MS*	*F*	*p-level*
Regression	1.	17.77237	17.77237	14.19187	0.00186
Residual	15.	18.78438	1.25229		
Total	16.	36.55675			

	Coefficients	*Standard Error*	*LCL*	*UCL*	*t Stat*	*p-level*	*H0 (2%) rejected?*
Intercept	5.73475	2.22063	-0.04439	11.51388	2.58249	0.02081	*No*
B	0.9724	0.25812	0.30064	1.64416	3.76721	0.00186	*Yes*

T (2%) 2.60248
LCL - Lower value of a reliable interval (LCL)
UCL - Upper value of a reliable interval (UCL)

Residuals

Observation	*Predicted Y*	*Residual*	*Standard Residuals*
1	-3.50877	-1.56181	-1.44142
2	-1.86809	0.33049	0.30501
3	-2.37011	0.53914	0.49758
4	-2.01106	-0.44935	-0.41471
5	-4.98528	0.38322	0.35368
6	-3.93715	1.36246	1.25743
7	-3.41631	-1.4076	-1.2991
8	-4.26081	-0.59306	-0.54735
9	-2.44543	0.67664	0.62448
10	-1.54663	-1.45337	-1.34133
11	-1.7193	-1.83355	-1.69221
12	-2.30249	0.70043	0.64644
13	-1.39672	0.11273	0.10404
14	-1.79397	-0.43082	-0.39761
15	-2.09579	0.69028	0.63707
16	-2.16782	1.41722	1.30797
17	-1.83186	1.51696	1.40003

APPENDIX F.1: Results of Statistical Analyses for Tier 2 Demonstration
Final Report, ER-0707

Linear Regression Log Native Hydraulic Conductivity vs Log Attenuation Factor (Sites)

Regression Statistics

R	0.54064
R Square	0.29229
Adjusted R Sq	0.11536
Standard Erroı	1.42641
Total Number	6

A =- 0.1071 + 0.3977 * B

ANOVA

	d.f.	*SS*	*MS*	*F*	*p-level*
Regression	1.	3.36132	3.36132	1.65205	0.26805
Residual	4.	8.13856	2.03464		
Total	5.	11.49988			

	Coefficients	*Standard Error*	*LCL*	*UCL*	*t Stat*	*p-level*	*H0 (2%) rejected?*
Intercept	-0.10713	2.00148	-7.60657	7.3923	-0.05353	0.95988	*No*
B	0.3977	0.30941	-0.76166	1.55705	1.28532	0.26805	*No*
T (2%)	3.74695						

LCL - Lower value of a reliable interval (LCL)
UCL - Upper value of a reliable interval (UCL)

Residuals

Observation	*Predicted Y*	*Residual*	*andard Residuals*
1	-3.21867	-1.85191	-1.45155
2	-3.21867	1.21867	0.95521
3	-3.38579	-0.09569	-0.07501
4	-1.38002	-1.10146	-0.86334
5	-2.06413	0.51128	0.40075
6	-2.14302	1.31911	1.03393

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APPENDIX F.1: Results of Statistical Analyses for Tier 2 Demonstration
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Linear Regression Log Soil Permeability vs. Log Attenuation Factor (Sites)

Regression Statistics

R	0.78515
R Square	0.61646
Adjusted R Sq	0.53975
Standard Error	1.10301
Total Number	7

A = 7.5272 + 1.1958 * B

ANOVA

	d.f.	*SS*	*MS*	*F*	*p-level*
Regression	1.	9.7774	9.7774	8.03652	0.03647
Residual	5.	6.0831	1.21662		
Total	6.	15.8605			

	Coefficients	*Standard Error*	*LCL*	*UCL*	*t Stat*	*p-level*	*H0 (2%) rejected?*
Intercept	7.5272	3.69844	-4.9178	19.97221	2.03524	0.09746	*No*
B	1.19577	0.42181	-0.22358	2.61511	2.83488	0.03647	*No*
T (2%)	3.36493						

LCL - Lower value of a reliable interval (LCL)
UCL - Upper value of a reliable interval (UCL)

Residuals

Observation	*Predicted Y*	*Residual*	*andard Residuals*
1	-4.2199	-0.85068	-0.84485
2	-1.98944	-0.01056	-0.01049
3	-4.82256	1.34108	1.33188
4	-3.53581	-1.2881	-1.27927
5	-1.8642	-0.61729	-0.61306
6	-1.76337	0.21053	0.20909
7	-2.03893	1.21502	1.2067

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APPENDIX F.1: Results of Statistical Analyses for Tier 2 Demonstration
Final Report, ER-0707

Linear Regression Moisture Content vs. Log Attenuation Factor (Sites)

Regression Statistics

R	0.61115
R Square	0.37351
Adjusted R Sq	0.24821
Standard Error	1.40972
Total Number (	7

A = 5.2302 - 9.9555 * B

ANOVA

	d.f.	*SS*	*MS*	*F*	*p-level*
Regression	1.	5.92401	5.92401	2.98094	0.14484
Residual	5.	9.93649	1.9873		
Total	6.	15.8605			

	Coefficients	*Standard Error*	*LCL*	*UCL*	*t Stat*	*p-level*	*H0 (2%) rejected?*
Intercept	5.2302	4.7336	-10.69803	21.15844	1.10491	0.31951	*No*
B	-9.95545	5.76613	-29.35809	9.44718	-1.72654	0.14484	*No*

T (2%) 3.36493

LCL - Lower value of a reliable interval (LCL)

UCL - Upper value of a reliable interval (UCL)

Residuals

Observation	*Predicted Y*	*Residual*	*andard Residuals*
1	-3.7297	-1.34088	-1.04195
2	-3.03282	1.03282	0.80257
3	-4.32703	0.84555	0.65705
4	-3.13238	-1.69153	-1.31444
5	-1.43995	-1.04154	-0.80934
6	-2.6346	1.08176	0.8406
7	-1.93772	1.11381	0.86551

APPENDIX F.2: Results of Statistical Analyses for Tier 3 Demonstration

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Welcome to Minitab, press F1 for help.
Retrieving worksheet from file: \\.host\Shared Folders\My
Desktop\3213_Tier3_Results_for_ANOVA_no_parris.xls
```

Results for: 3213_Tier3_Results_for_ANOVA_no_parris.xls

General Linear Model: RPD versus Matrix, LocationID, Source, Site

```
Factor     Type Levels Values
Matrix    fixed      2 Indoor Air Sub-slab
Location  fixed      3 1          2          3
Source    fixed      2 Above ground Subsurface
Site     random      5 Hill AFB          Jacksonville NAS  Moffett Field NAS
                       Tinker AFB        Travis AFB
```

Analysis of Variance for RPD, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Matrix	1	13.4783	13.5215	13.5215	22.56	0.005 x
Location	2	0.9285	0.6851	0.3426	0.87	0.446 x
Source	1	65.1097	32.7295	32.7295	10.48	0.030 x
Site	4	15.1115	15.4628	3.8657	2.11	0.515 x
Matrix*Location	2	0.4429	0.1714	0.0857	0.09	0.913 x
Matrix*Source	1	7.1325	3.2122	3.2122	2.50	0.182 x
Matrix*Site	4	2.4511	2.4800	0.6200	0.42	0.787 x
Location*Source	2	2.2053	1.1890	0.5945	0.51	0.614 x
Location*Site	8	3.0349	3.0629	0.3829	0.29	0.934 x
Source*Site	4	14.3149	14.2377	3.5594	2.07	0.263 x
Matrix*Location*Source	2	0.5063	0.1948	0.0974	0.11	0.898 x
Matrix*Location*Site	8	8.2935	8.1090	1.0136	1.05	0.475
Matrix*Source*Site	4	5.5311	5.6677	1.4169	1.46	0.299 x
Location*Source*Site	8	10.0959	10.1425	1.2678	1.31	0.356
Matrix*Location*Source* Site	8	7.7483	7.7483	0.9685	2.04	0.044
Error	174	82.6027	82.6027	0.4747		
Total	233	238.9870				

x Not an exact F-test.

Unusual Observations for RPD

Obs	RPD	Fit	SE Fit	Residual	St Resid
56	0.57426	-1.05941	0.39780	1.63366	2.90R
58	0.24997	-1.24963	0.39780	1.49960	2.67R
116	1.71429	0.03395	0.28129	1.68034	2.67R
118	-1.93701	0.03395	0.28129	-1.97095	-3.13R
119	1.64486	0.03395	0.28129	1.61091	2.56R
122	1.17073	-0.49218	0.28129	1.66292	2.64R
124	-1.96694	-0.49218	0.28129	-1.47476	-2.34R

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APPENDIX F.2: Results of Statistical Analyses for Tier 3 Demonstration

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149	1.45324	-0.01514	0.28129	1.46838	2.33R
154	-1.93701	0.03395	0.28129	-1.97095	-3.13R
160	-1.94089	-0.49218	0.28129	-1.44870	-2.30R
179	-1.57724	0.02993	0.28129	-1.60716	-2.56R
181	1.42593	0.12047	0.28129	1.30546	2.08R
185	1.40807	0.12047	0.28129	1.28761	2.05R
187	1.00000	-0.33255	0.26042	1.33255	2.09R
189	-1.75335	-0.33255	0.26042	-1.42080	-2.23R
191	1.00000	-0.33255	0.26042	1.33255	2.09R
213	1.94937	0.02993	0.28129	1.91944	3.05R

R denotes an observation with a large standardized residual.

General Linear Model: RPD versus Matrix, Source, Site

```
Factor     Type Levels Values
Matrix    fixed      2 Indoor Air Sub-slab
Source    fixed      2 Above ground Subsurface
Site     random      5 Hill AFB         Jacksonville NAS  Moffett Field NAS
                       Tinker AFB       Travis AFB
```

Analysis of Variance for RPD, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Matrix	1	13.4783	13.7079	13.7079	23.43	0.004 x
Source	1	65.1999	33.0252	33.0252	10.48	0.030 x
Site	4	15.1143	15.4718	3.8680	1.39	0.456 x
Matrix*Source	1	7.1105	3.1271	3.1271	2.47	0.182 x
Matrix*Site	4	2.4380	2.3689	0.5922	0.43	0.784
Source*Site	4	14.3343	14.3343	3.5836	2.59	0.190
Matrix*Source*Site	4	5.5341	5.5341	1.3835	2.56	0.040
Error	214	115.7777	115.7777	0.5410		
Total	233	238.9870				

x Not an exact F-test.

Unusual Observations for RPD

Obs	RPD	Fit	SE Fit	Residual	St Resid
59	-1.99958	-0.42088	0.24518	-1.57870	-2.28R
60	-1.99928	-0.42088	0.24518	-1.57841	-2.28R
116	1.71429	-0.15779	0.17337	1.87208	2.62R
118	-1.93701	-0.15779	0.17337	-1.77921	-2.49R
119	1.64486	-0.15779	0.17337	1.80265	2.52R
124	-1.96694	-0.15779	0.17337	-1.80915	-2.53R
145	-0.35294	1.11997	0.17337	-1.47291	-2.06R
149	1.45324	-0.15779	0.17337	1.61103	2.25R
150	-0.40741	1.11997	0.17337	-1.52738	-2.14R
154	-1.93701	-0.15779	0.17337	-1.77921	-2.49R
160	-1.94089	-0.15779	0.17337	-1.78309	-2.49R
181	1.42593	-0.00467	0.17337	1.43060	2.00R
189	-1.75335	-0.00467	0.17337	-1.74868	-2.45R

APPENDIX F.2: Results of Statistical Analyses for Tier 3 Demonstration

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```
213   1.94937  -0.25709     0.17337   2.20646      3.09R
225  -1.60144  -0.00467     0.17337  -1.59677     -2.23R
```

R denotes an observation with a large standardized residual.

Results for: 3213_Tier3_Results_for_ANOVA_Indoor.xls

General Linear Model: RPD versus LocationID, Source, Site

```
Factor     Type Levels Values
Location  fixed      3 1          2          3
Source    fixed      2 Above ground Subsurface
Site     random      5 Hill AFB          Jacksonville NAS  Moffett Field NAS
                       Tinker AFB        Travis AFB
```

Analysis of Variance for RPD, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Location	2	0.9171	0.6538	0.3269	0.77	0.482 x
Source	1	64.9711	32.4176	32.4176	10.30	0.030 x
Site	4	15.1269	15.4186	3.8546	1.43	0.442 x
Location*Source	2	2.1611	1.1838	0.5919	0.51	0.617 x
Location*Site	8	3.0406	3.1003	0.3875	0.31	0.942
Source*Site	4	14.3913	14.2765	3.5691	2.84	0.097 x
Location*Source*Site	8	10.0433	10.0433	1.2554	1.99	0.049
Error	203	128.1282	128.1282	0.6312		
Total	232	238.7795				

x Not an exact F-test.

Unusual Observations for RPD

Obs	RPD	Fit	SE Fit	Residual	St Resid
25	1.98542	-0.05303	0.32434	2.03845	2.81R
31	1.97838	0.52226	0.32434	1.45612	2.01R
98	-1.57724	0.15460	0.23954	-1.73183	-2.29R
114	1.94937	0.15460	0.23954	1.79477	2.37R
143	-1.99958	-0.05303	0.32434	-1.94655	-2.68R
144	-1.99928	-0.05303	0.32434	-1.94625	-2.68R
170	1.71429	-0.17417	0.22934	1.88845	2.48R
172	-1.93701	-0.17417	0.22934	-1.76284	-2.32R
173	1.64486	-0.17417	0.22934	1.81903	2.39R
178	-1.96694	-0.31707	0.22934	-1.64987	-2.17R
190	-1.93701	-0.17417	0.22934	-1.76284	-2.32R
196	-1.94089	-0.31707	0.22934	-1.62382	-2.13R
199	1.42593	-0.21487	0.22934	1.64080	2.16R
203	1.40807	-0.21487	0.22934	1.62294	2.13R
218	-0.52582	1.07002	0.22934	-1.59583	-2.10R

R denotes an observation with a large standardized residual.

APPENDIX F.2: Results of Statistical Analyses for Tier 3 Demonstration

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Results for: 3213_Tier3_Results_for_ANOVA_subslab.xls

General Linear Model: RPD versus LocationID, Source, Site

```
Factor     Type Levels Values
Location  fixed      3 1          2          3
Source    fixed      2 Above ground Subsurface
Site     random      5 Hill AFB          Jacksonville NAS  Moffett Field NAS
                       Tinker AFB        Travis AFB

Analysis of Variance for RPD, using Adjusted SS for Tests

Source                 DF     Seq SS     Adj SS     Adj MS       F      P
Location                2     1.1458     0.7080     0.3540    0.31  0.740 x
Source                  1    14.5695     7.7135     7.7135    5.15  0.078 x
Site                    4    13.3158    13.7861     3.4465    4.42  0.540 x
Location*Source         2     2.2956     1.1351     0.5676    0.30  0.747 x
Location*Site           8     9.9898     9.8086     1.2261    0.59  0.766
Source*Site             4     6.5305     6.5732     1.6433    0.79  0.565 x
Location*Source*Site    8    16.7142    16.7142     2.0893    3.40  0.002
Error                  87    53.4028    53.4028     0.6138
Total                 116   117.9639

x Not an exact F-test.

Unusual Observations for RPD

Obs        RPD        Fit      SE Fit  Residual   St Resid
 23    0.57426  -1.05941     0.45234   1.63366      2.55R
 25    0.24997  -1.24963     0.45234   1.49960      2.34R
 53    1.71429   0.03395     0.31985   1.68034      2.35R
 55   -1.93701   0.03395     0.31985  -1.97095     -2.76R
 56    1.64486   0.03395     0.31985   1.61091      2.25R
 59    1.17073  -0.49218     0.31985   1.66292      2.33R
 61   -1.96694  -0.49218     0.31985  -1.47476     -2.06R
 68    1.45324  -0.01514     0.31985   1.46838      2.05R
 73   -1.93701   0.03395     0.31985  -1.97095     -2.76R
 79   -1.94089  -0.49218     0.31985  -1.44870     -2.03R

R denotes an observation with a large standardized residual.
```

Environmental Security Technology Certification Program
(ESTCP)

FINAL REPORT

Proposed Tier 2 Screening Criteria and Tier 3 Field Procedures for Evaluation of Vapor Intrusion
ESTCP Project ER-200707

Appendix G: Points of Contact

Environmental Security Technology Certification Program
(ESTCP)

FINAL REPORT

Proposed Tier 2 Screening Criteria and Tier 3 Field Procedures for Evaluation of Vapor Intrusion
ESTCP Project ER-200707

Appendix G: Points of Contact

POINT OF CONTACT	ORGANIZATION	Phone/Fax/Email	Role in Project
Tom McHugh	GSI Environmental Inc. 2211 Norfolk Street, Suite 1000 Houston, Texas 77098	Ph: 713-522-6300 Fax: 713-522-8010 temchugh@gsi-net.com	Principal Investigator and contact for SE Texas Industrial Site
Dr. Sam Brock	AFCEE 3300 Sidney Brooks Brooks City-Base Tx, 78235	Ph: 210-536-4329 Fax: 210-536-4330 Samuel.Brock@brooks.af.mil	Contracting Officer's Rep.
Bob Patton	TCEQ MC 136 P.O. Box 13087 Austin, TX 78711-3087	Ph: 512-239-2277 RPATTON@tceq.texas.gov	Site Contact: Pioneer Cleaners Site
Glenn Anderson	411 Airmen Drive Building 570 Travis AFB CA 94535-2001	Ph: (707) 424-4359 Fax: (707) 424-0833 glenn.anderson@travis.af.mil	Site Contact; Travis AFB Site
Mike Singletary, P.E.	NAVFAC Southeast P.O. Box 190010, 2155 Eagle Drive North Charleston, SC 29419-9010	Ph: (843) 820-7357 Fax: (843) 820-7465 michael.a.singletary@navy.mil	Site Contact: Jacksonville NAS, Parris Island
John Osweiler	Project Manager Parsons Midwest City, Oklahoma	Ph: (405) 455-4155 john.osweiler@parsons.com	Site Contact: Tinker AFB
Kyle Gorder	75CEG/CEVR 7274 Wardleigh Rd Hill AFB Utah 84056-5137	Ph: 801-775-2559 kyle.gorder@hill.af.mil	Site Contact: Hill AFB

Environmental Security Technology Certification Program
(ESTCP)

FINAL REPORT

Proposed Tier 2 Screening Criteria and Tier 3 Field Procedures for Evaluation of Vapor Intrusion
ESTCP Project ER-200707

POINT OF CONTACT	ORGANIZATION	Phone/Fax/Email	Role in Project
Ignacio Rivera-Duarte	SPAWAR Systems Center Pacific Code 71752, Environmental Analysis and Compliance 53475 Strothe Rd. San Diego, CA 92152-6343	Ph: (619) 553-2373 ignacio.rivera@navy.mil	Site Contact: Moffett Field NAS and SPAWAR OTC
Casey J. Haskell	Environmental Engineering Section GeoEnvironmental Branch US Army Corps of Engineers New England District 696 Virginia Road Concord, MA 01742-2721	Ph: 978-318-8398 Casey.J.Haskell@usace.army.mil	Site Contact: Fmr NIKE Facility